

**The Adventures of
ARCHIBALD HIGGINS**

EVERYTHING IS RELATIVE

Jean-Pierre Petit



The Association Knowledge without Borders, founded and chaired by Professor Jean-Pierre Petit, astrophysicist, aims at spreading scientific and technical knowledge in as many countries as possible and in as many languages as possible. To this end, all his popular scientific works, which cover a period of thirty years, and more particularly the illustrated albums he has created, are now freely accessible. Anyone is now free to duplicate the present file, either in digital form or in the form of printed copies and circulate these copies to libraries, within the context of schools or universities or associations whose aims would be the same as the association, provided that they do not derive any profit from this circulation and that they do not have any political, sectarian or confessional connotations. These pdf files may also be put on line in the computer networks of school and university libraries.



Jean-Pierre Petit intends to create numerous other works which will be accessible to a larger audience. Even illiterate people will be able to read them because the written parts will “speak” when the readers click on them. Thus it will be possible to use these works to support literacy schemes. Other albums will be “bilingual” in so far as it will be possible to switch from one language to another selected language with a mere click. Hence another tool made available to develop language skills.

Jean-Pierre Petit was born in 1937. He made his career in French research. He worked as a plasma physicist, he directed a computer science centre, he has created softwares, he has published hundreds of articles in scientific magazines, dealing with subjects ranging from fluid mechanics to theoretical cosmology. He has published about thirty books which have been translated in numerous languages.

The association can be contacted on the following internet site:

<http://savoir-sans-frontieres.com>

SOPHIE, I
SOMETIMES WONDER...

WHAT, SWEETHEART?


... I DUNNO... IF THINGS ARE
WHAT THEY SEEM... IF REALITY IS
REALLY REAL...

IF MAYBE
THERE'S SOMETHING
BEHIND
EVERYTHING.

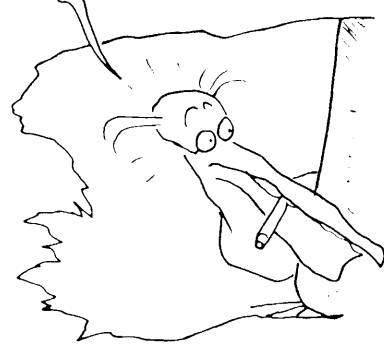
TAKE NOTE! ONE UNIVERSE
CAN HIDE ANOTHER.



YOU'VE ONLY GOT TO GO AND LOOK!



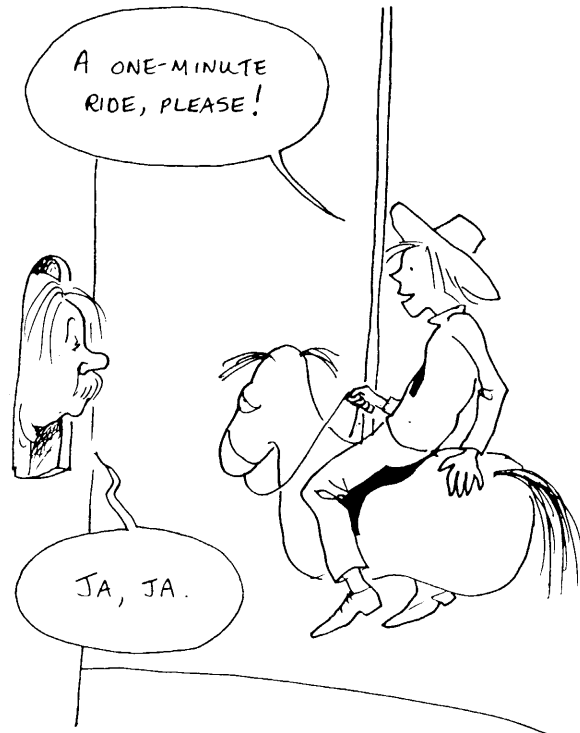
SOMEBODY'S PLAYING
A VIOLIN.



BLIMEY! THAT'S TORN IT!
WE'RE IN THE BLINKIN'
CATACOMBS OF PHYSICS.

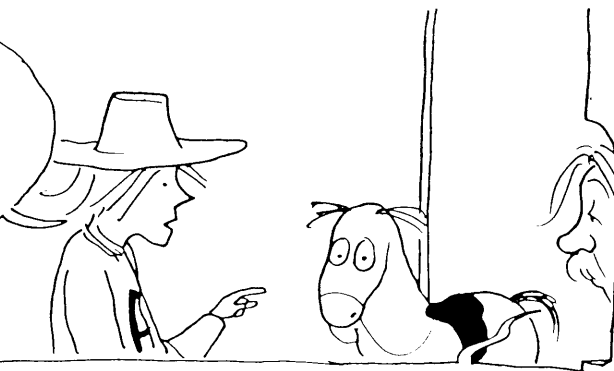
COME ON! THIS
IS GOING TO BE
ABSOLUTELY FASCINATING!



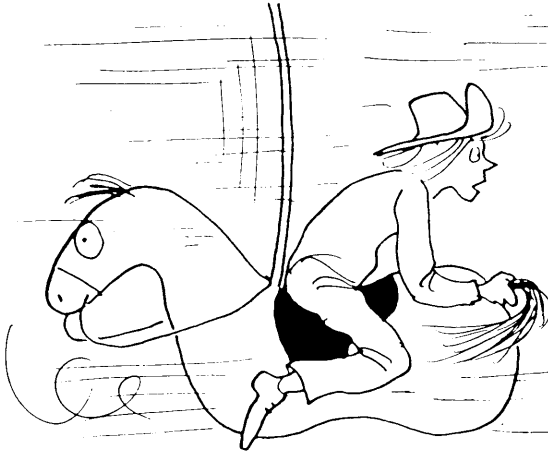




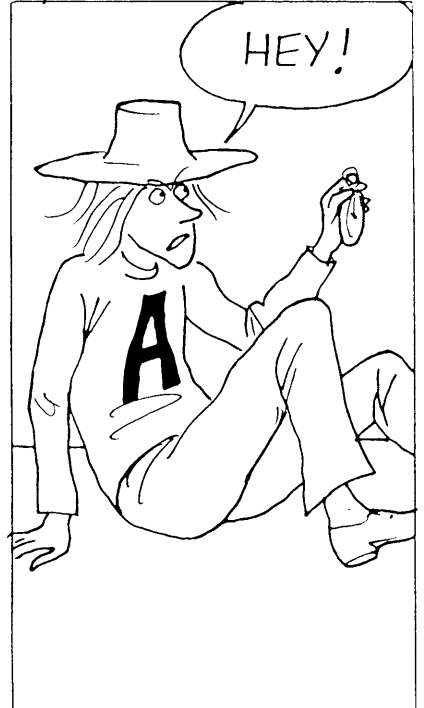
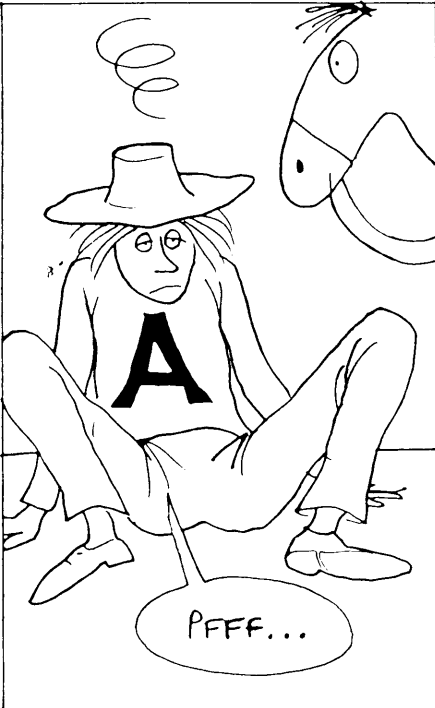
MR. ALBERT - IS IT
POSSIBLE TO MAKE THE
MERRY-GO-ROUND TURN
THE OTHER WAY?

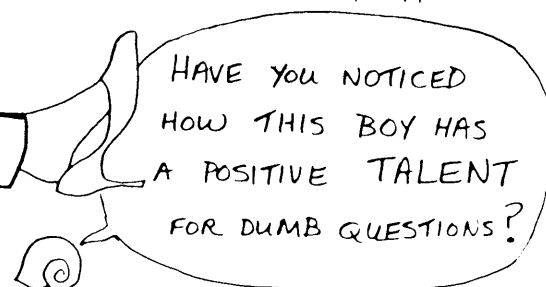
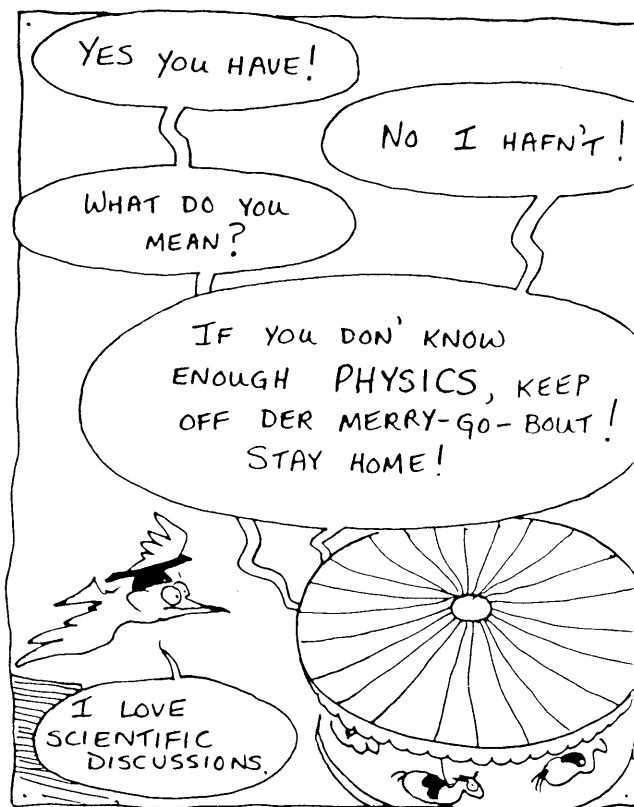


JA, NO PROBLEM. IT'S STILL \$1 PER MINUTE, THOUGH.

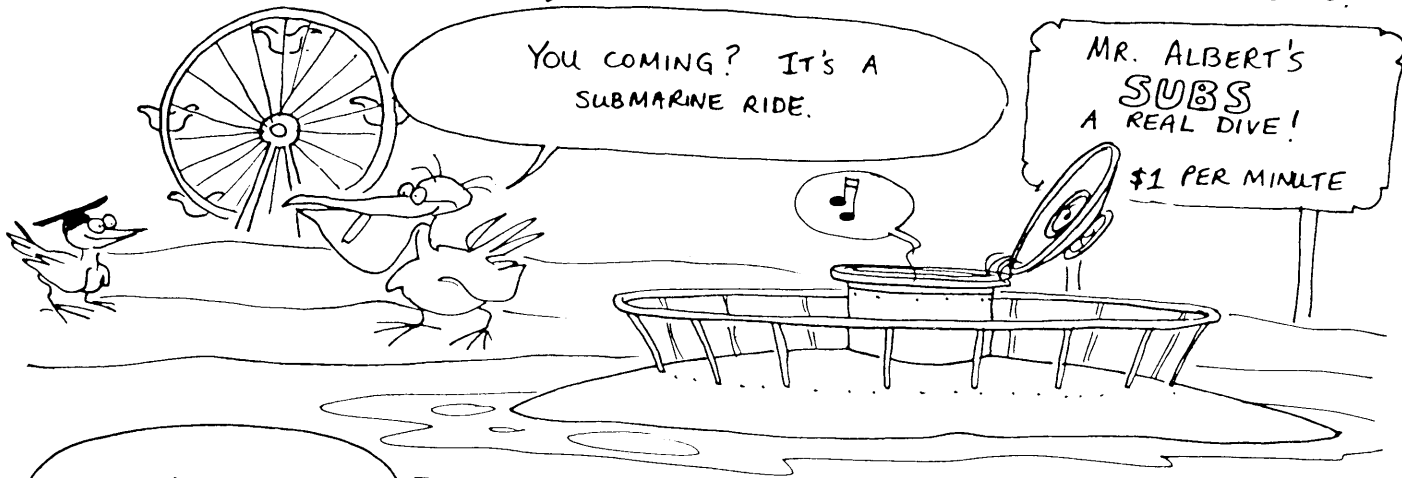


TIME'S
UP!





MEANWHILE, BACK AT THE FAIR ...



IS DER TIME VAT'S
FLOWINK, JA? DER OLD
PRINCIPLE OF DER
CLEPSYDRA.

AH, OF COURSE. AND
THE RATE OF FLOW IS PROPORTIONAL
TO THE DIFFERENCE BETWEEN
THE PRESSURE IN THE
RESERVOIR, AND THE
PRESSURE OUTSIDE.

MEIN SUBMARINE IS EQUIPPED MIT
DIVING PLANES, SO DAT DER FASTER
SHE GOES, DER MORE SHE DIFES.

AN' THAT MEANS THAT
TER MEASURE ITS SPEED,
ORL YER NEEDS IS A BLINKIN'
MANOMETER WOT'LL
MEASURE THE H'EXTERMINABLE
PRESSURE...

CRIPES,
I GOTTIT!

I SAY, IT HAS A
MEAN TURN OF SPEED,
YOUR MACHINE!

H'OKAY, HUP VE
GO! DER MINUTE
IS YUST RUN OUT.

HEY, WOT'S
GOING ON? WE'RE
ON PAGE 25.

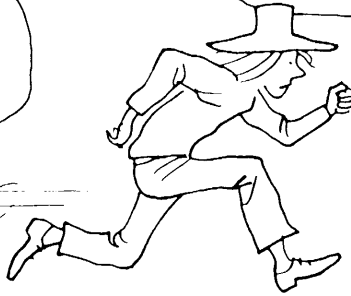
BUT FOR THE MOMENT WE MUST LEAVE MAX AND LENNY TO SORT OUT THE CONSEQUENCES OF THEIR UNDERWATER ADVENTURE, AND RETURN TO ARCHIE...



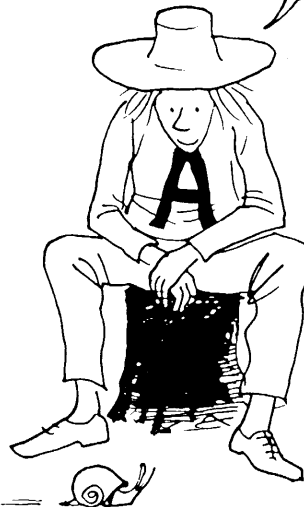
IT'S KINDA WEIRD, WHEN YOU THINK ABOUT IT. IF YOU MOVE IN SPACE, THEN WHATEVER DIRECTION YOU CHOOSE, YOU ALWAYS SEEM TO BE ABLE TO RETRACE YOUR STEPS AND GO THE OPPOSITE WAY.

WASTE OF BREATH.

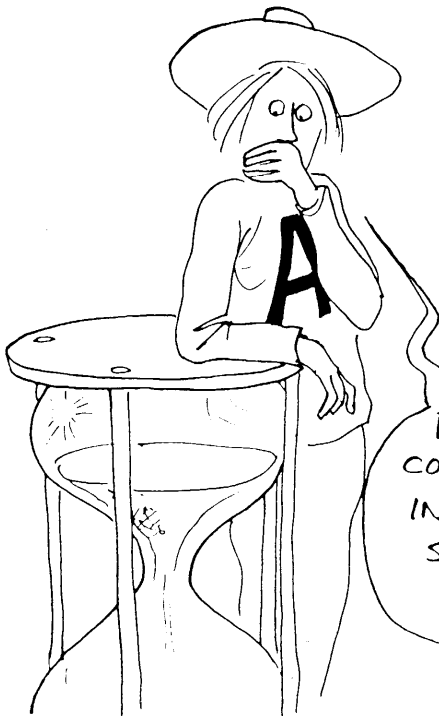
TIRESIAS CAN ONLY GO AT A SNAIL'S PACE, SO IT'S EASY FOR ME TO OVERTAKE HIM.



OR I CAN STOP, AND LET HIM OVERTAKE ME.



BUT WHEN IT COMES TO MOVING IN TIME, THINGS SEEM TO BE A LITTLE DIFFERENT...





WELL, I GUESS
IT'S FORBIDDEN TO
STAY HERE...

... UNDER PENALTY OF NOT
BEING ABLE TO START UP AGAIN.



PERSON NAME OF TIRESIAS?
A REGISTERED PARCEL
FOR YOU.



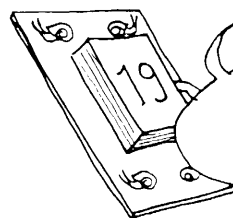
MR. OR
MRS. ?



MAKES NO
DIFFERENCE.



HMMMM - IT'S
A CALENDAR.



THAT'S RIGHT, ARCHIE. EVERY
TIME YOU PULL A PAGE OFF,
ANOTHER DAY PASSES.

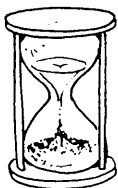


SPACE - TIME



SOPHIE - WHAT
IS TIME ?

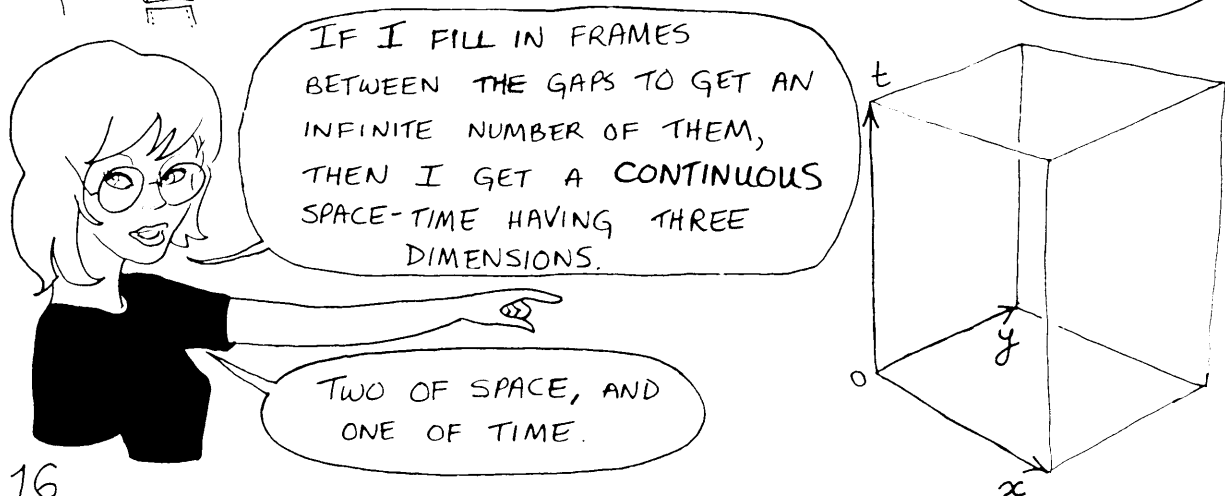
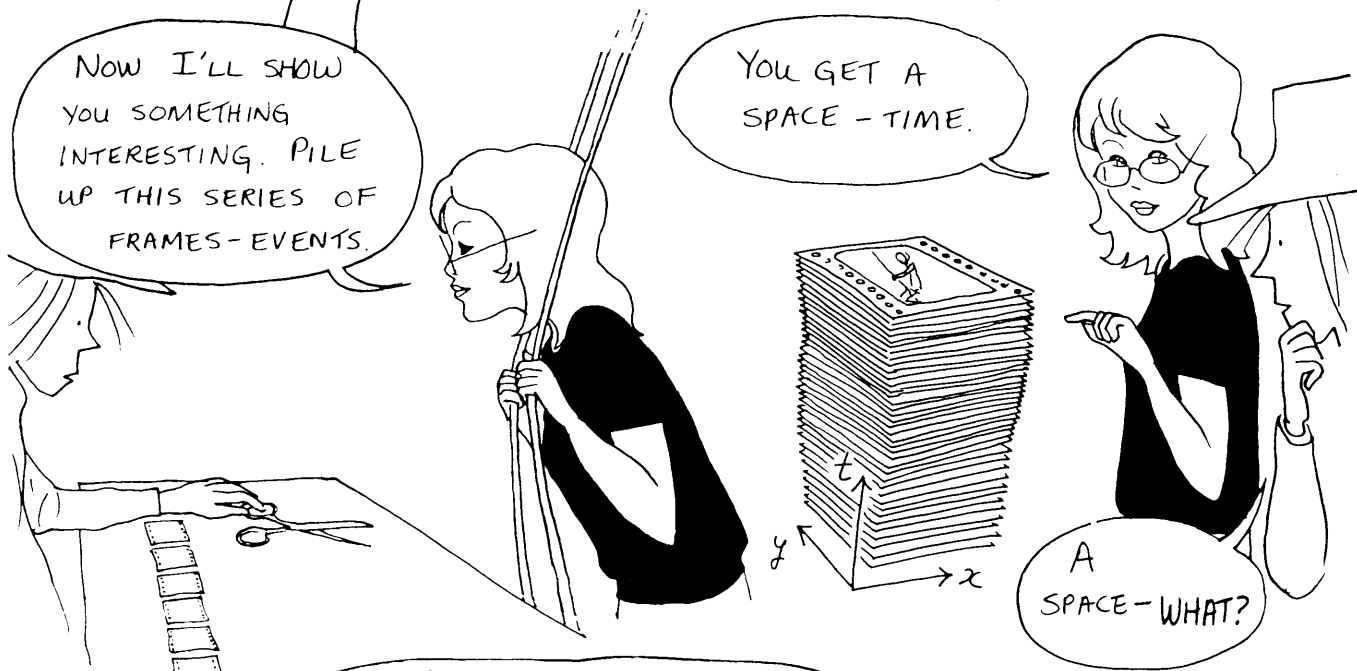
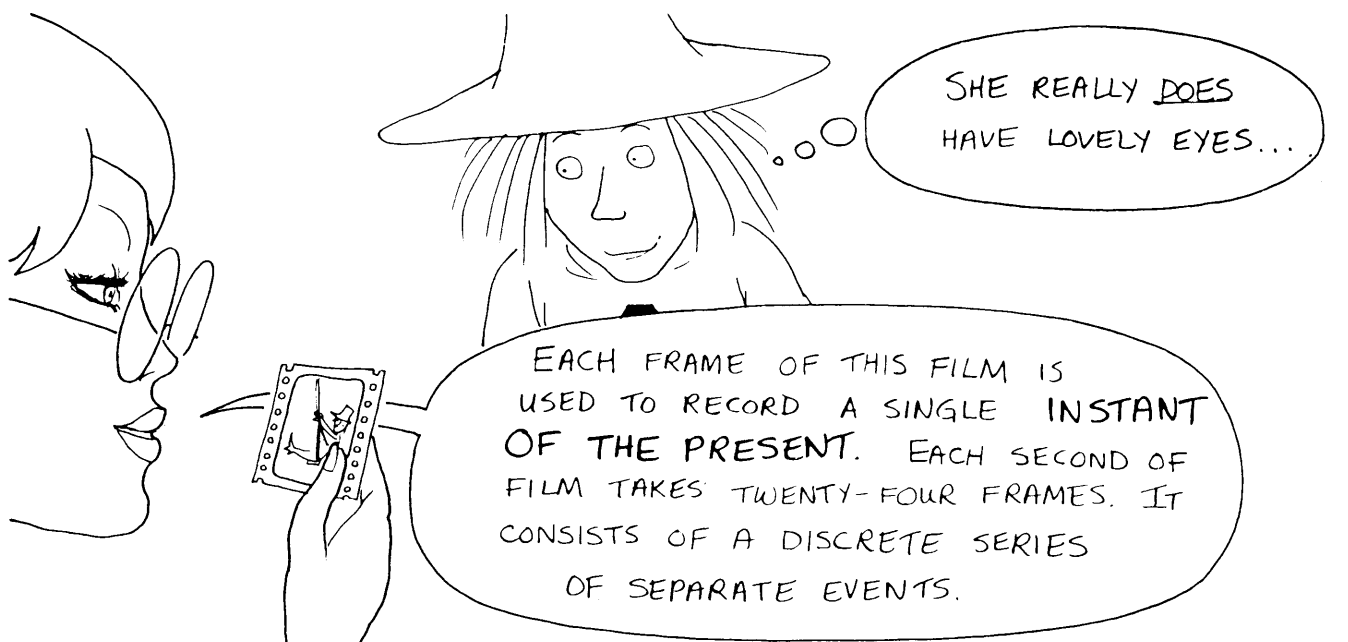
IT'S A DIMENSION,
LIKE ALL THE OTHERS.
CLIMB ON THE SWING
AND I'LL EXPLAIN.



WHAT AN
EGG- STRAORDINARY
DEE- VICE !









REMEMBER THAT THE NUMBER OF DIMENSIONS FOR A **SPACE** IS JUST THE NUMBER OF QUANTITIES REQUIRED TO DETERMINE THE POSITION OF A **POINT** IN THAT SPACE.

WE LIVE IN A SPACE-TIME HAVING FOUR DIMENSIONS. FOR INSTANCE, YOU NEED FOUR QUANTITIES - FOUR ITEMS OF DATA - TO BE ABLE TO MEET SOMEBODY AT THE RIGHT PLACE AND TIME.

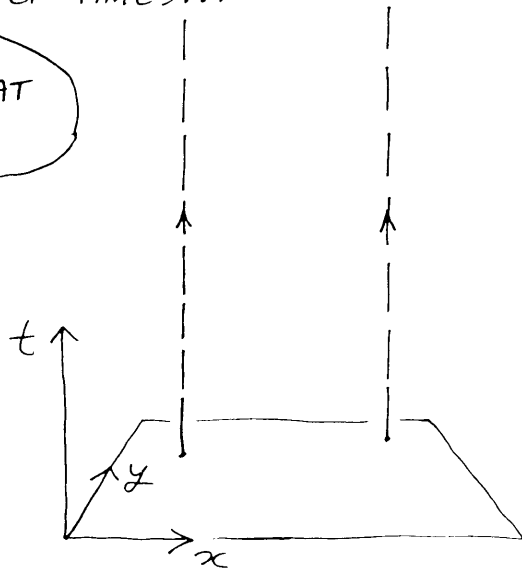
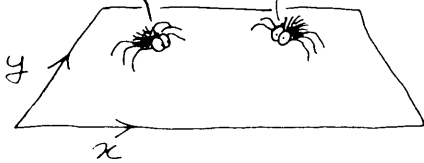
TIRESIAS HAS ASKED ME TO MEET HIM AT NUMBER TWELVE ON FOURTH STREET ON THE THIRD FLOOR. BUT THE CLOD HAS FORGOTTEN TO SAY WHEN. I DON'T HAVE FOUR ITEMS OF DATA!



BUT TO MAKE LIFE EASIER FOR THE ARTIST, LET'S CONTINUE TO THINK ABOUT A THREE-DIMENSIONAL SPACE-TIME (TWO OF SPACE, ONE OF TIME)...

DID YOU REALIZE, OLD BOY, THAT WE MOVE IN TIME?

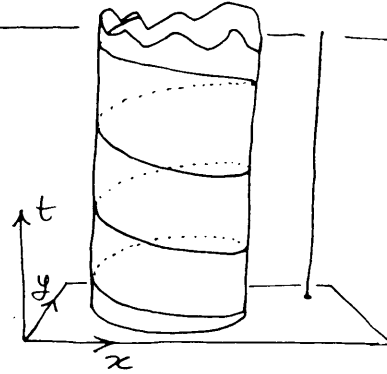
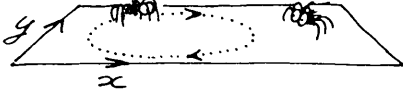
BUT I HAVEN'T BUDGED AN INCH!



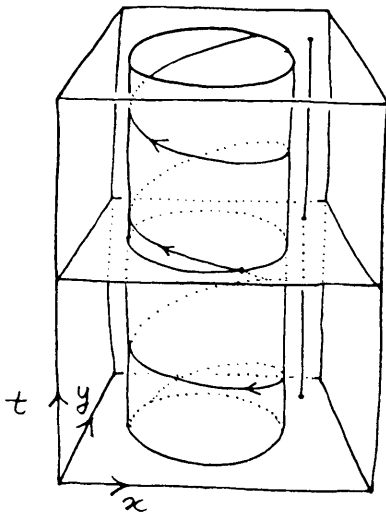
THE MOTION OF THESE TWO SPIDERS IN SUCH A SPACE-TIME IS ILLUSTRATED BY THE DIAGRAM ON THE RIGHT.

FOR INSTANCE, IF I GO ROUND AND ROUND IN CIRCLES, THEN MY PATH THROUGH THREE-DIMENSIONAL SPACE-TIME WILL LOOK LIKE A COILED SPRING (OR HELIX).

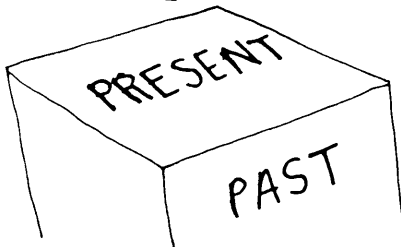
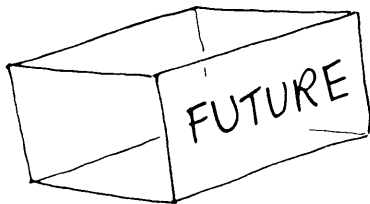
GOSH - IS IT SPRING ALREADY?



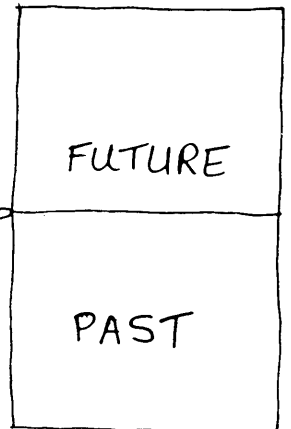
LET'S CHECK THAT I'VE UNDERSTOOD. THE ABSOLUTE PRESENT, AT ANY GIVEN MOMENT, IS A PLANE SLICE CUT THROUGH THIS SPACE-TIME.

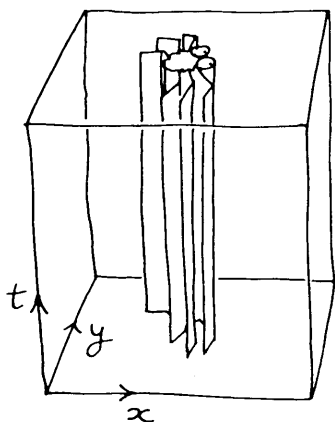


ABOVE IT IS THE FUTURE
AND BELOW IT IS THE PAST.

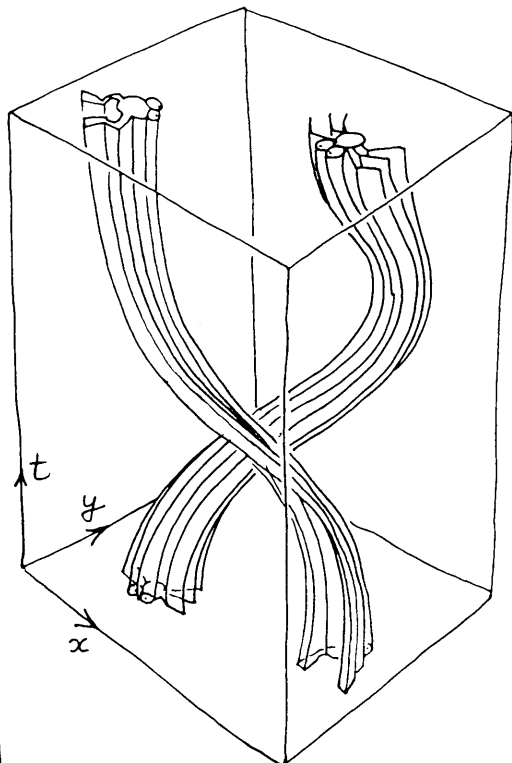


THE FIRST PERSON TO
REALIZE THAT THE PRESENT
HAS ZERO THICKNESS
WAS ARISTOTLE.





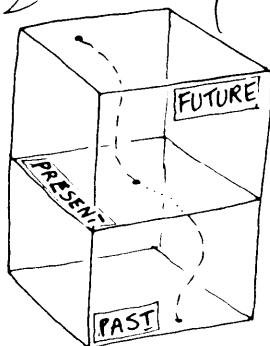
TO BE COMPLETELY ACCURATE, WE SHOULD REPRESENT A STATIONARY SPIDER IN THREE-DIMENSIONAL SPACE-TIME LIKE THIS.



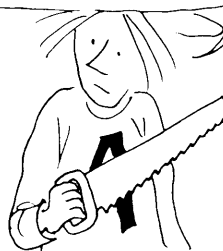
THE SPIDER'S SURVIVAL DEPENDS ON ITS PATH, IN SPACE-TIME, FAILING TO MEET THE PATH TRACED BY THE FROG.



CLOSE ENCOUNTER OF THE SPATIO-TEMPORAL KIND.

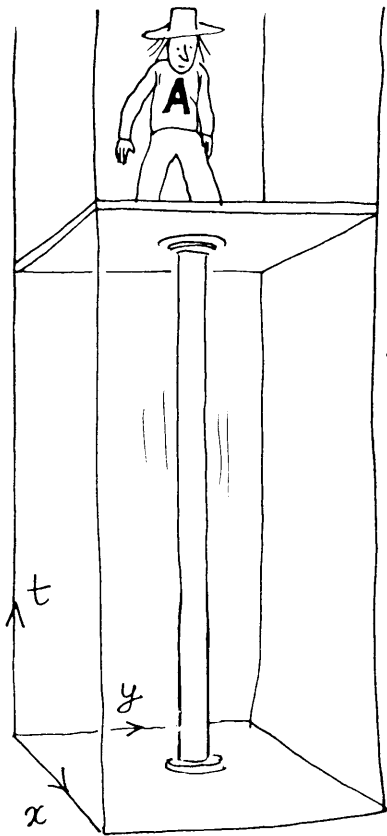


BUT WHY DON'T WE SEE THESE SPACE-TIME TRAJECTORIES?



BECAUSE WE CAN ONLY EVER SEE THE PRESENT!

THE ELEVATOR OF TIME PROPELS US
INEXORABLY UPWARD. IT NEITHER STOPS,
NOR FALLS BACK.



MON TUES WED THURS FRI SAT SUN

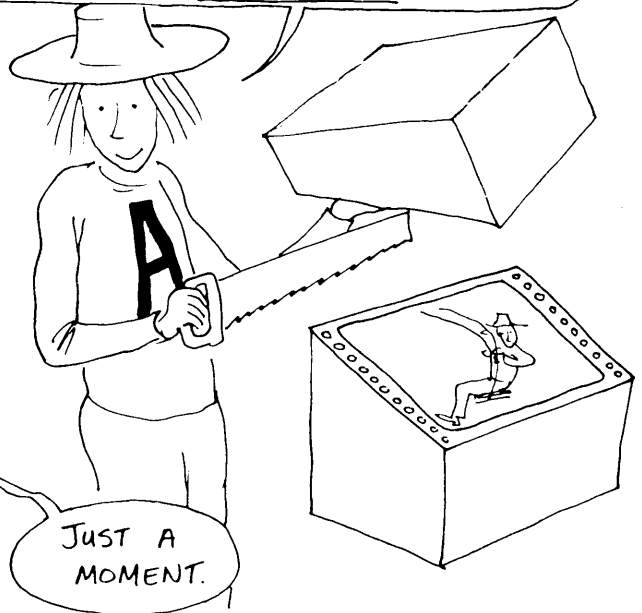
AN ELEVATOR
WITH NO DOOR...

... AND NO CONTROLS...
HOLY COW!

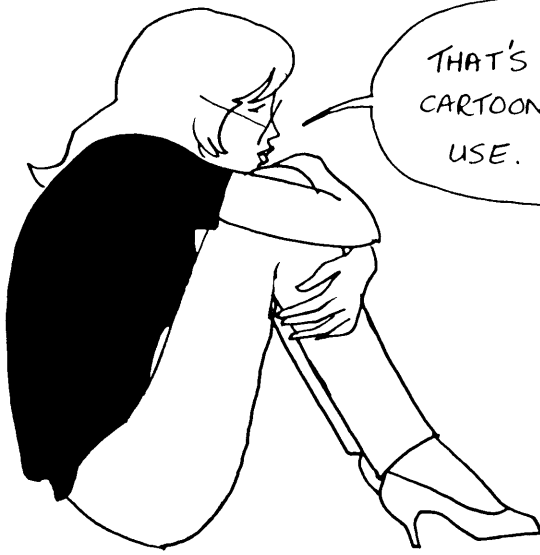
I'M GLAD SOPHIE'S
HERE.



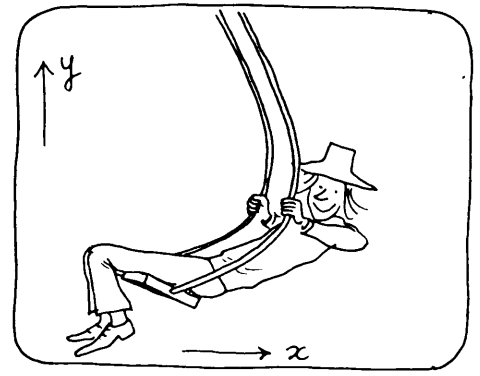
LOOK, SOPHIE — I'VE FOUND A NEW
SLANT ON THINGS! I'VE CUT
SPACE-TIME OBLIQUELY.



JUST A
MOMENT.



THAT'S A TRICK
CARTOONISTS OFTEN
USE.



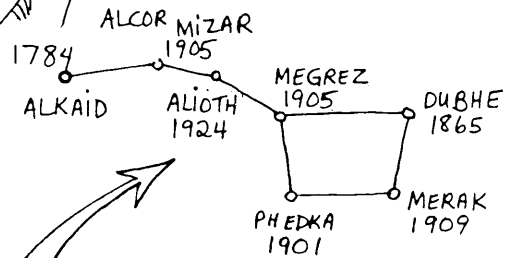
LIGHT CONES



YOU PROBABLY HAVEN'T NOTICED THIS —
BUT WE ALWAYS SEE AN OBLIQUE
CROSS-SECTION OF REALITY.



OH SURE,
'COURSE I HAVE.
EH?



LIGHT TAKES A DEFINITE AMOUNT OF
TIME TO REACH US FROM DISTANT OBJECTS.
THE DIAGRAM SHOWS THE TIME AT WHICH LIGHT
LEFT THE STARS IN THE BIG DIPPER, SO AS
TO ARRIVE **NOW**.



WALL STREET:
ENTROPY ON
THE UP
AGAIN

TIME MAGAZINE
FLASH NEWS!
SUPERNOVA
IN
ANDROMEDA!

YOU MEAN THAT NEARBY
STARS COULD BLOW UP, AND I
WOULDN'T KNOW ABOUT IT FOR
YEARS?

NOBODY EVER
TELLS ME ANYTHING...

THE IMAGE OF
ANDROMEDA THAT WE OBSERVE
THROUGH TELESCOPES SHOWS US HOW
IT WAS TWO MILLION YEARS AGO.

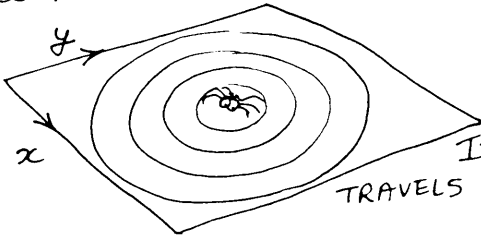
WE SEE THE SUN THE
WAY IT WAS **EIGHT**
MINUTES AGO.

AND MY FEET
ARE OLDER
THAN MY NOSE!

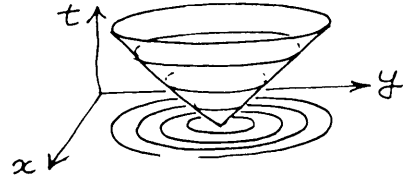
SO THERE'S REALLY
NOTHING HARDER TO
SEE THAN THE PRESENT.
MAYBE AN OBJECT
SITUATED JUST BEHIND
MY RETINA... ??

No, ARCHIE. WE CAN ONLY SEE
THE PAST. SO AT ANY INSTANT WHAT
WE SEE IS THE **RELATIVE PRESENT**,
WHEREAS WHAT WE WERE TALKING ABOUT
BEFORE WAS THE **ABSOLUTE PRESENT**.
THE PRESENT IS STRICTLY A **PERSONAL**
THING; YOU CAN'T SHARE IT AROUND.

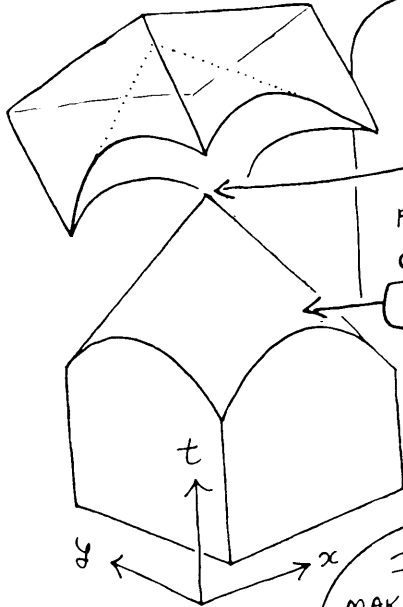
LET'S TAKE THE DISCUSSION FURTHER.
WAVES ON THE SURFACE OF WATER
TRAVEL AT A CONSTANT SPEED. HERE A
SPIDER HAS FALLEN INTO A POND, EMITTING
CONCENTRIC CIRCULAR WAVES.



IN SPACE-TIME THIS MESSAGE
SPREADS OUT ALONG A CONE.



IT'S EXACTLY THE SAME FOR LIGHT, WHICH
TRAVELS AT A CONSTANT SPEED OF 300,000 KM/SEC.



IN THE SAME WAY, THE
LIGHT SIGNALS RECEIVED BY
EACH
OBSERVER COME
FROM POINTS SITUATED ON A
CONE IN SPACE-TIME: THE
LIGHT CONE.

IT'S THIS THAT
MAKES UP THE OBSERVER'S
RELATIVE PRESENT.

YOU MEAN...
THE SKY IS A
CONE?

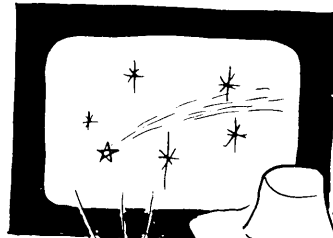
YES, ARCHIE; IT'S A THREE-DIMENSIONAL
CONICAL CROSS-SECTION OF OUR
FOUR-DIMENSIONAL SPACE-TIME.



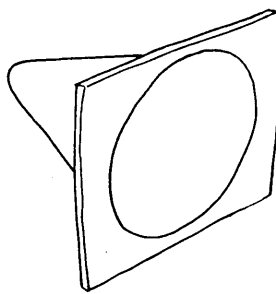
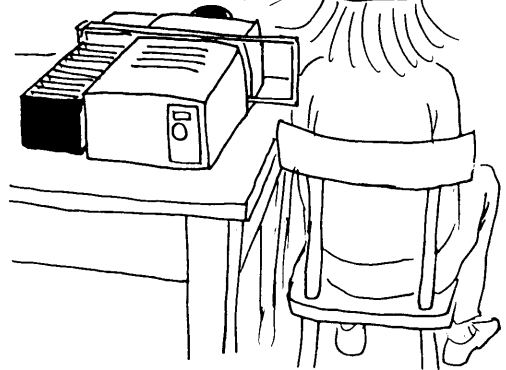
A THREE-DIMENSIONAL
CONE?

IS THAT LIKE A
TRIPLE SCOOP?

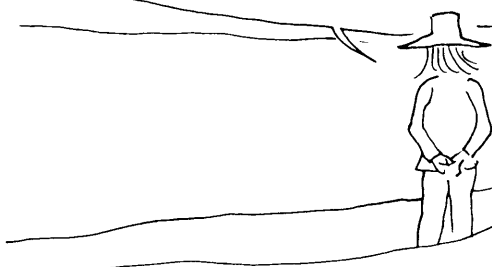
IT'S A CONCEPT THAT
THE HUMAN BRAIN FINDS
DIFFICULT TO ACQUIRE. OUR
PERCEPTIONS, AND ALSO OUR
THOUGHTS, TAKE PLACE IN
THREE DIMENSIONS, NOT FOUR.
SO LET'S MAKE A HASTY RETURN
TO OUR MODEL OF A
THREE-DIMENSIONAL SPACE-TIME.



IT'S REALLY QUITE ILLUMINATING, WATCHING
SPACE-TIME LIKE THIS. BUT I SUPPOSE, TO DO IT
PROPERLY, I OUGHT TO USE **CONICAL** SLIDES.



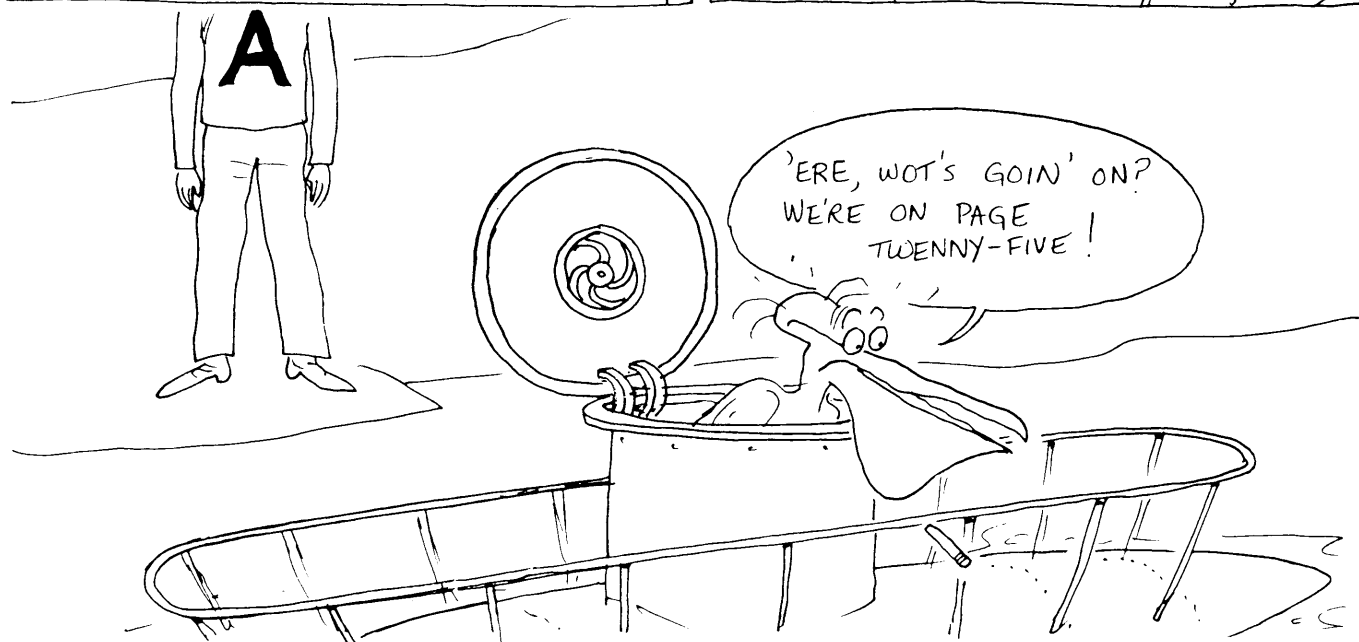
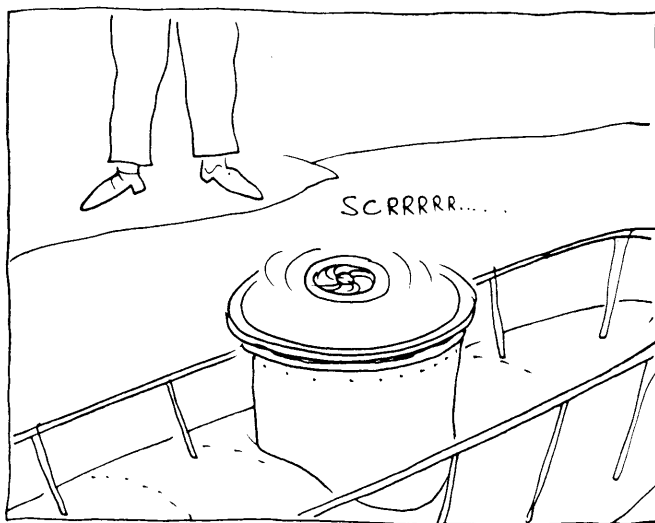
WOOPS - I FORGOT ALL ABOUT
MAX AND LENNY! IT'S BEEN
FIFTEEN PAGES SINCE THEY VANISHED!



WHEN THEY LEFT, THEY WERE GETTING INTO
A SUBMARINE FOR A JOURNEY TAKING EXACTLY ONE
MINUTE... BUT IT'S BEEN AGES LONGER THAN
THAT SINCE THEY DISAPPEARED!



AH, HERE THEY COME, SURFACING
AT LAST. THEY CERTAINLY TOOK THEIR
TIME.







NAR LOOK - THAT... CLEPSYDRABLE THINGY WOT MR. ALBERT 'AD... THE 'YDROLICK WOTSIT... DID IT REELY TELL THE TIME IN THE SUBMARINE?



OH, JA. LIKE I TOL' YOU DER CLEPSYDRA IS FED FROM A RESERVOIR AT A CONSTANT PRESSURE P_R . IT FLOWS TO DER OUTSIDE OF DER SUBMARINE, VERE DER PRESSURE IS P_E . SO DER RATE OF FLOW IS PROPORTIONAL TO DER PRESSURE-DIFFERENCE $P_R - P_E$.



DER FASTER DER SUBMARINE GOES, DER DEEPER SHE GOES, AN' DER MORE DER PRESSURE P_E INCREASES. SO DER LESS FLUID DER CLEPSYDRA LOSES. IN OTHER VORDS: DER FASTER YOU GO, DER LESS TIME PASSES.



SOUNDS LIKE A LOAD OF OLD GARBAGE TO ME! HOW WOULD TIME FLOW FOR SOMEONE WHO WAS MOTIONLESS?



MOTIONLESS RELATIVE TO WHAT?

IT'S DER RATE OF FLOW OF A REFERENCE CLEPSYDRA VOT'S PLACED IN A SUBMARINE AT ANCHOR, MOTIONLESS - HENCE ON DER SURFACE.



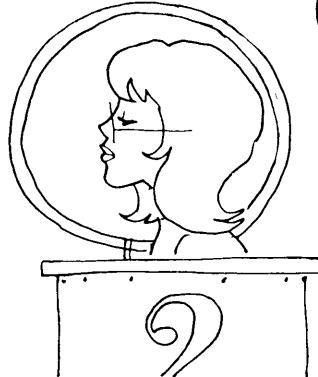
I'LL SORT THIS OUT ONCE AND FOR ALL!



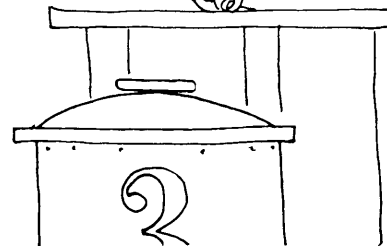
I WONDER WHAT IT'S LIKE TO BE MOTIONLESS?

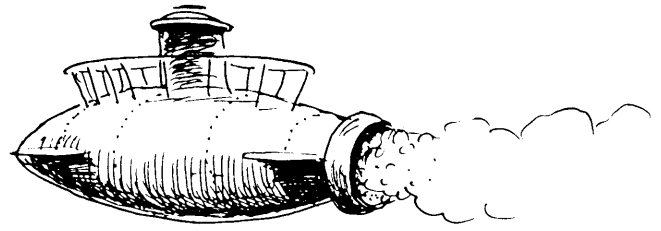
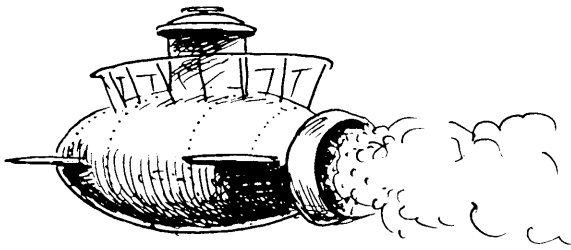
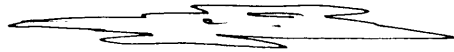
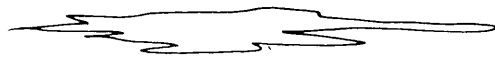


SOPHIE: YOU TAKE NUMBER 2 AND I'LL TAKE NUMBER 1. WE'LL LEAVE NUMBER 3 HERE AT THE MARINA, AND SAIL THE OTHER TWO AT THE SAME VELOCITY \vec{v} .



THIS IS ONE DIVE I'M HAPPY TO STAY OUT OF!





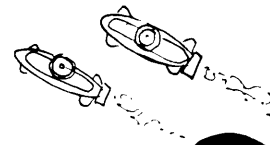
OH, WOW, LOOK! A CONVOY! THEY'RE GOING AT THE SAME SPEED V , IN THE SAME DIRECTION, AND AT THE SAME DEPTH.

PEOPLES VOT DO EXPERIMENTS ARE PEOPLES VOT'S NOT GOT ANY CONFIDENCE IN DEMSELS.

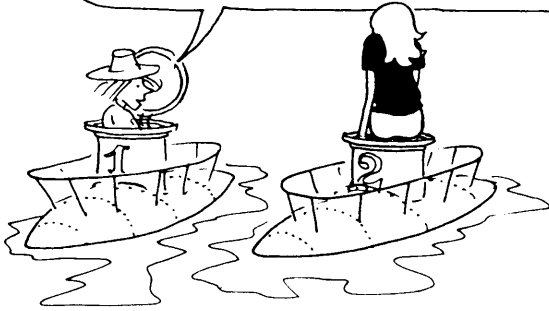
MR. ALBERT, SIR; WHAT IS MOTION?

BLEB
BLEB
BLEB

DAT'S A GOOT QVESTION, TIRESIAS. DER T'ING VOT ACTUALLY EXISTS IS DER RELATIVE SPEED - DER SPEED OF VUN BODY RELATIVE TO ANUDDER. IT'S REALLY QVITE ARBITRARY TO ASSUME, AS VE USUAL DOES, DAT VUN OBJECT - OR GROUP OF OBJECTS (YOU, ME, AND DER MARINA) - IS AT REST. IN FACT, ALL MOTION IS RELATIVE. SO, FOR EXAMPLE... AT DIS MOMENT SOPHIE AND ARCHIBALD, WHO ARE MOVING RELATIVE TO US, ARE MOTIONLESS RELATIVE TO EACH OTHER.



WE'RE BACK WHERE WE STARTED; OUR CLEPSYDRAS HAVE EXPELLED THE SAME AMOUNT OF WATER; AND THE SAME TIME t' HAS PASSED.



TWO SYSTEMS THAT ARE MOTIONLESS RELATIVE TO EACH OTHER ARE SYNCHRONOUS.



IT'S QUITE DIFFERENT FOR THE REMAINING CLEPSYDRA, NUMBER 3, WHICH WAS AT REST ON THE SURFACE. IT SHOWS A LONGER ELAPSED TIME t .



YOU KNOW, MR. ALBERT, THERE'S SOMETHING THAT BOTHERS ME ABOUT YOUR THEORIES.

HMMPH.

VOT, JUNG MAN?



WELL... AT THE SURFACE YOU CAN MEASURE THE DISTANCE D WE'VE GONE, AND THE TIME t THAT IT'S TAKEN, BY USING THE CLEPSYDRA IN SUBMARINE NUMBER 3. THAT GIVES A SPEED $v = \frac{D}{t}$.

THOSE ARE MEASUREMENTS MADE BY AN OBSERVER AT REST.

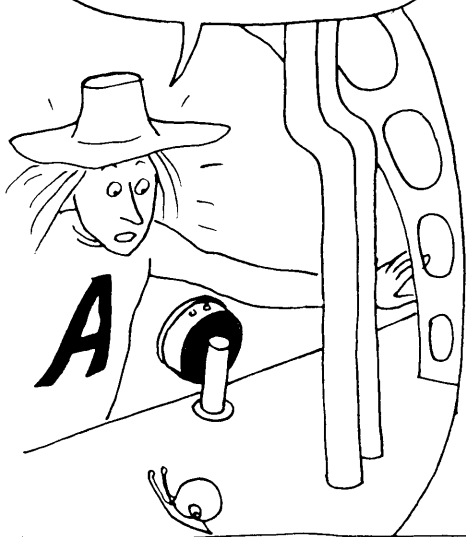


BUT IN SUBMARINES 1 AND 2, TIME FLOWED MORE SLOWLY.
IF WE'D MEASURED THE SPEED, WE SHOULD HAVE GOT A VALUE
 $V' = \frac{D}{t'}$, WHICH IS BIGGER THAN $V = \frac{D}{t}$.

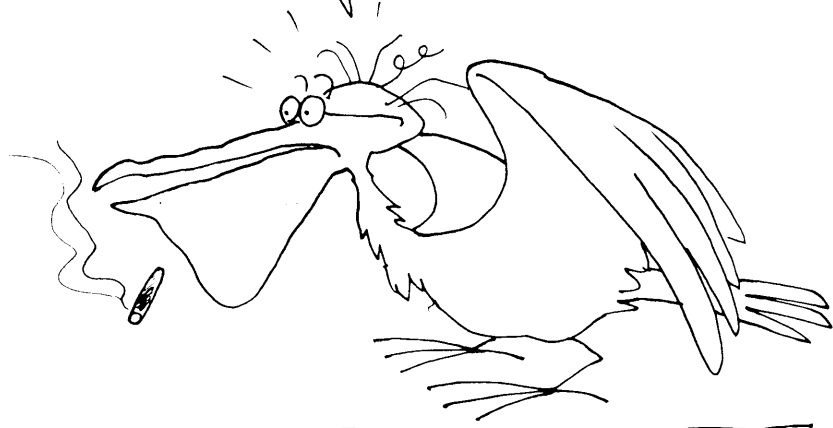


YOU HAFN'T CONSULTED DER LOCH OF YOUR
SUBMARINE (*). DAT VILL TELL YOU DER DISTANCE D'
YOU'F TRAFELLED.

HOLEY MOLEY!
D' IS LESS THAN D!



EVERYBODY'S GORN
BONKERS. I ALWAYS KNEW
IT'D 'APPEN!



(*) THE LOCH IS A NAVIGATIONAL INSTRUMENT THAT TELLS YOU THE
DISTANCE YOU HAVE TRAVELED.

THE LORENTZ CONTRACTION



IT LOOKS LIKE
 $\frac{D}{t}$ AND $\frac{D'}{t'}$ ARE EQUAL.
I GET THE SAME SPEED
BOTH WAYS!

BUT... THAT MEANS
SPACE GETS SQUORSHED
UP LIKE A BLOOMIN'
H'ACCORDYON, DUNNIT?



OH 'ECK...

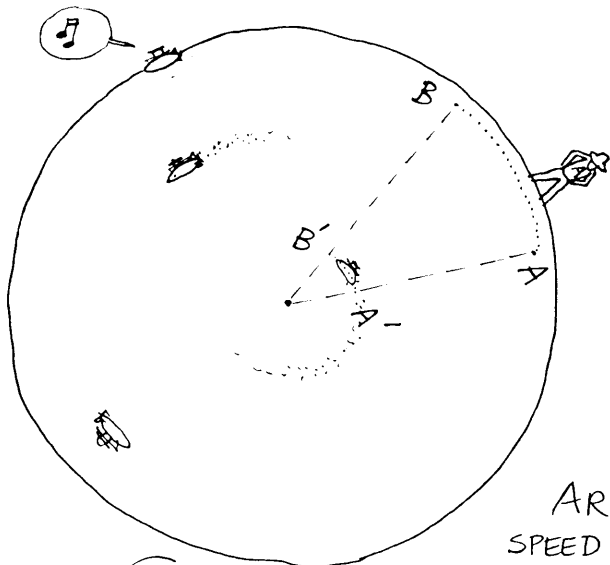
TIMES AND LENGTHS ARE
ONLY APPEARANCES. THERE'S
NO MORE AN ABSOLUTE TIME
THAN THERE IS ABSOLUTE
SPACE.



THINK BACK TO COSMIC PARK
AND ITS OCEAN, CHRONOS. BUT
REMEMBER THOSE WERE ONLY MODELS,
DESIGNED TO HELP US UNDERSTAND
THE STRANGE STRUCTURE OF
SPACE-TIME.



TO GET AN IDEA OF THIS SHRINKAGE OF LENGTHS, OR LORENTZ CONTRACTION (NAMED FOR ITS DISCOVERER), WE HAVE TO THINK OF COSMIC PARK AS SOME KIND OF LIQUID SPHERE.



ARCHIE'S SUBMARINE, TRAVELING AT SPEED V , HAS TO DIVE, SO IT FOLLOWS THAT, ARC $\widehat{A'B'} = D'$ IN A PROPER TIME, MEASURED ON BOARD, EQUAL TO t' . FOR AN OBSERVER AT REST AT THE SURFACE, THIS MOVEMENT IS SEEN AS THE ARC $\widehat{AB} = D$, IN A TIME t . AND WE HAVE

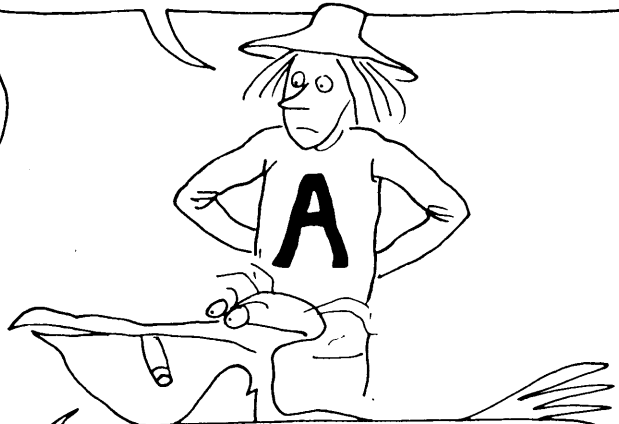
$$\frac{D'}{t'} = \frac{D}{t} = V.$$

IT'S AMUSING TO SEE THAT IN THIS MODEL, THE MOTION IS ANGULAR, AND IT'S PERCEPTION THAT TRANSFORMS IT INTO DISTANCE.



BUT WHY COME UP WITH SOMETHING
AS COMPLICATED AS THAT? TIME
THAT SLIPS, SPACE THAT SHRINKS...
A JERRY-BUILT UNIVERSE!

NEIN, NEIN. IT'S
BECAUSE OF DER SPEED OF
LIGHT, MY BOY. YOU'LL
SOON SEE...



YEAH, I'M SURE H'IT'LL ORL
BE VERY ILLUMINAYTIN'.

WELL, IT'S ALL VERY FASCINATING, THESE
COCK-AND-BULL STORIES ABOUT BLOBS OF WATER,
SUBMARINES, AND CONTRACTING LENGTHS. BUT
WHAT DOES IT ALL MEAN PHYSICALLY?

BACK ON YOUR TRUSTY CHARGER,
MY KNIGHT IN SHINING ARMOR!



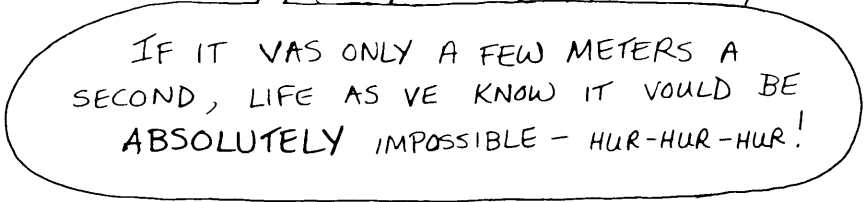
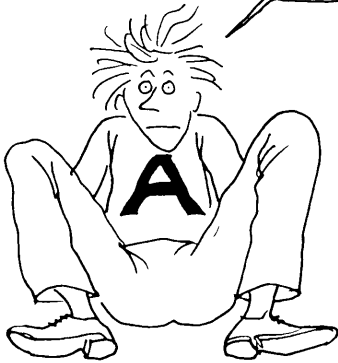
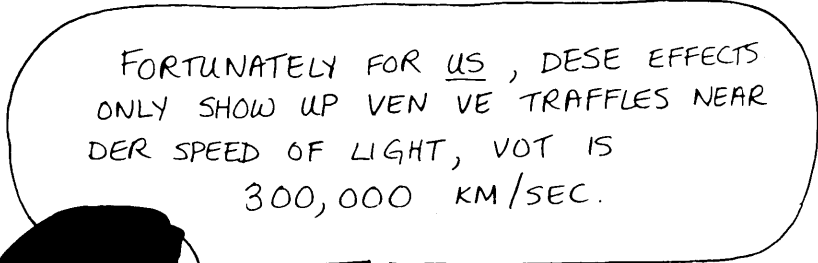
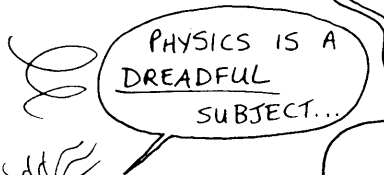
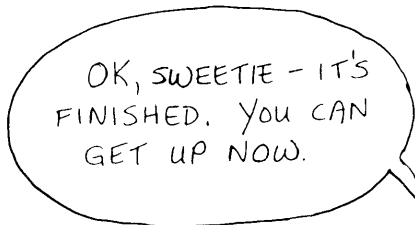
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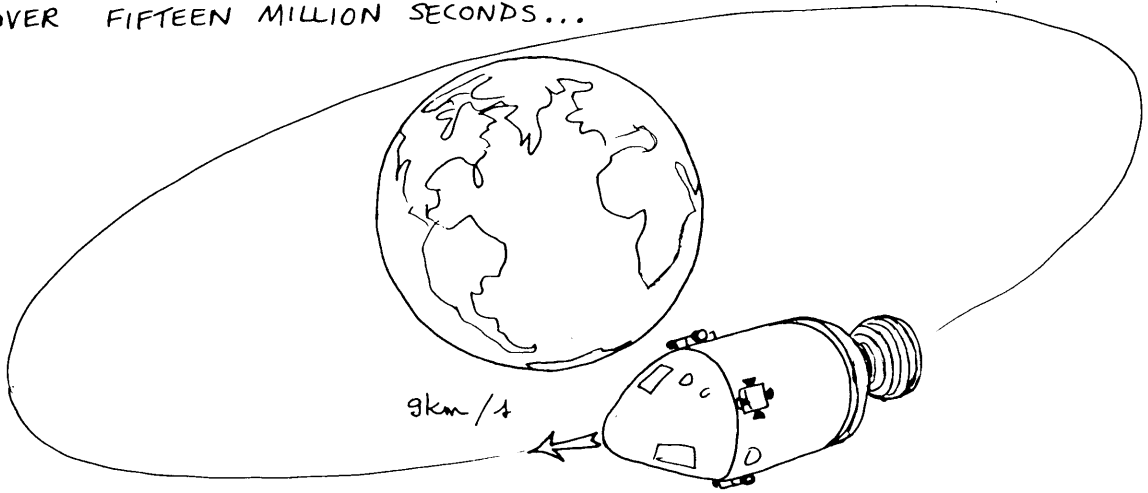
I BET THIS
NEVER HAPPENED
TO SIR
LANCELOT.



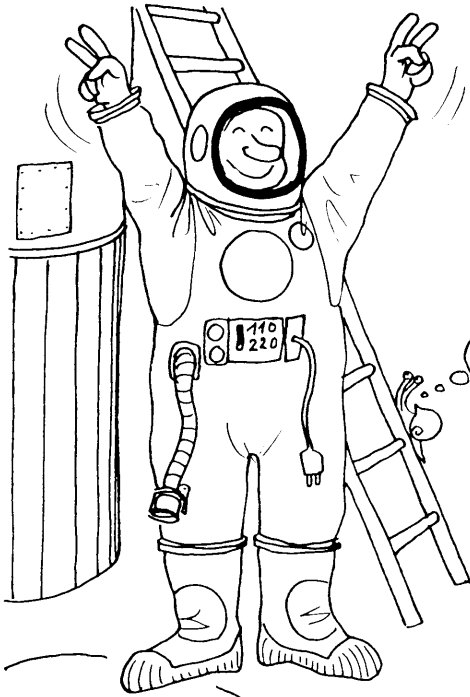
YOU VILL SEE
VOT YOU VILL SEE.



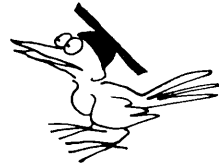
IF AN ASTRONAUT WERE TO STAY IN ORBIT FOR SIX MONTHS, THAT IS, OVER FIFTEEN MILLION SECONDS...



... THEN HIS AGE WOULD BE RETARDED BY 1.4 HUNDREDTHS OF A SECOND.



NOT THAT IT WOULD BE EXACTLY WRITTEN ON HIS FACE WHEN HE CAME BACK.



THE WORLD OF RELATIVITY SEEMS A LONG WAY REMOVED FROM EVERYDAY LIFE.

AT THE MOMENT IT'S ONLY OF INTEREST TO SPECIALISTS
IN HIGH ENERGY PHYSICS(*)...



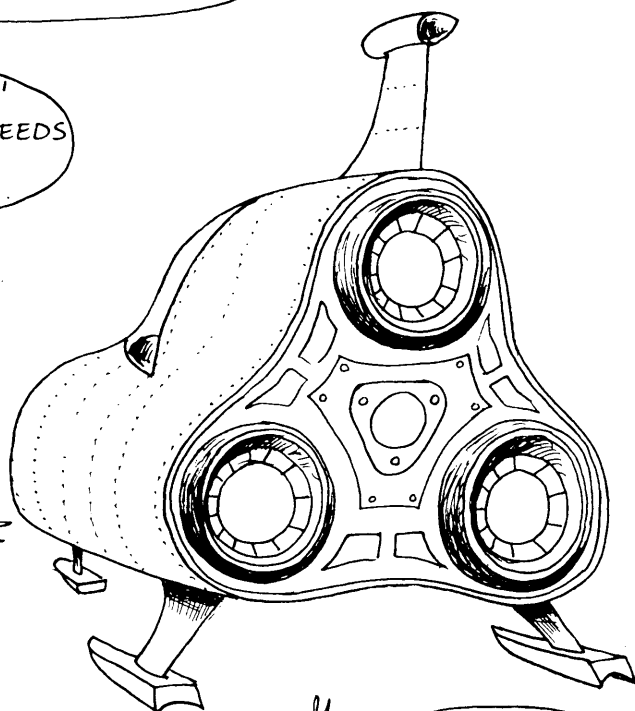
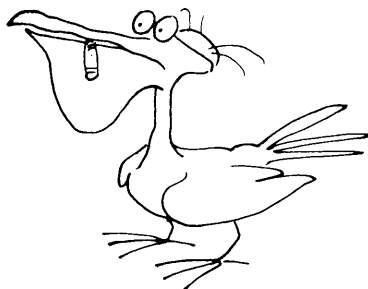
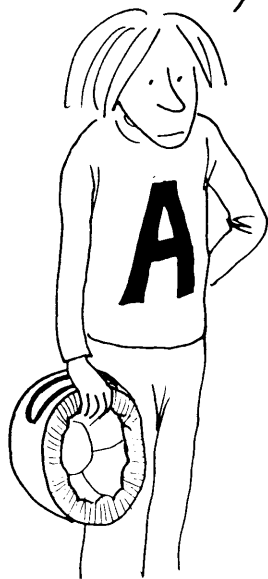
... AND CERTAIN GOVERNMENT AGENCIES...



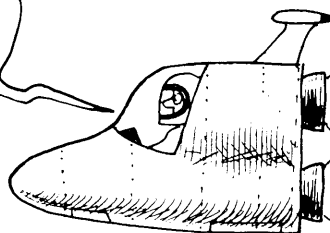
(*) ALSO CALLED PLUTOPHYSICS BECAUSE IT'S NOT EXACTLY CHEAP...

WHEN I GO FASTER, DOES IT REALLY
CAUSE THE UNIVERSE TO SHRINK?

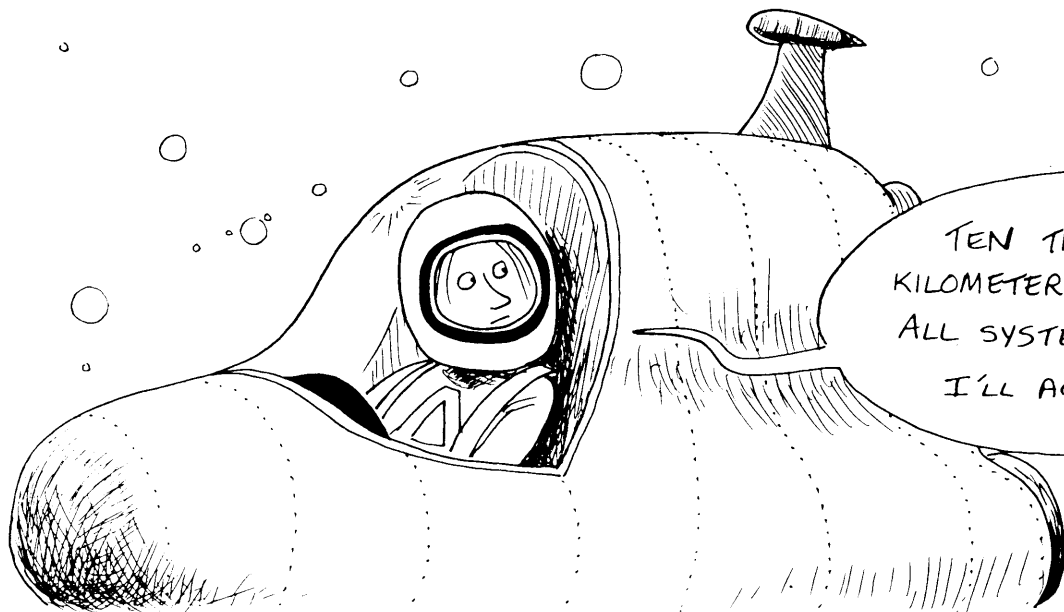
SOMETHIN'
ROUND HERE NEEDS
A SHRINK, I
CAN TELL YA.



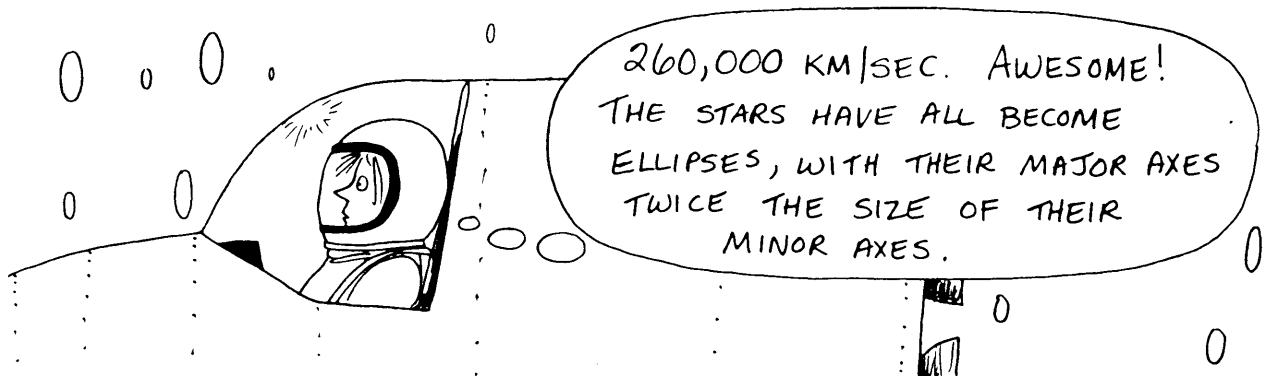
ENTERPRISE TO
MISSION CONTROL:
WE HAVE
LIFT-OFF.



THAT'S REALLY
A SPACED-OUT
CORVETTE...

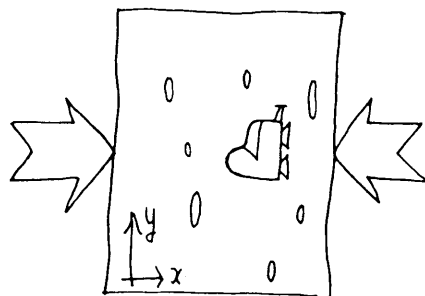
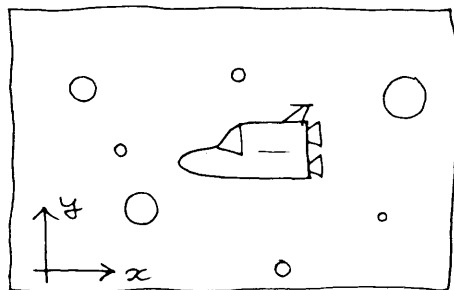


TEN THOUSAND
KILOMETERS PER SECOND.
ALL SYSTEMS NORMAL.
I'LL ACCELERATE!

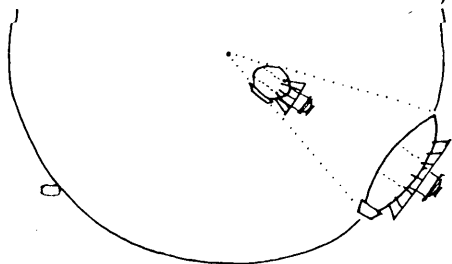


MEMORANDUM

IN FACT ARCHIBALD HIGGINS COULD NOT REALLY OBSERVE THIS LORENTZ CONTRACTION, FOR THE EXCELLENT REASON THAT EVERYTHING CONTRACTS: THE UNIVERSE, ARCHIBALD, AND HIS SHUTTLE.



IN THE SAME WAY, TRAVELERS IN COSMIC PARK DON'T NOTICE ANY SHRINKAGE.



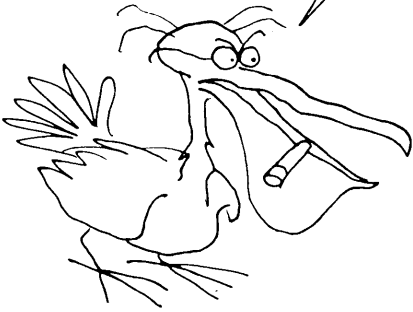
The Boss

SO IF I SPEED UP A BIT - LITTLE OLD ME, TIRESIAS THE SNAIL - I SQUASH UP THE ENTIRE UNIVERSE LIKE AN ACCORDION IN THE DIRECTION I'M MOVING.



WHAT POWER!

THAT'S REE-DICKLUS! A TIDDLY LITTLE
SNAIL CAN'T SHRINK THE 'OLE BLOOMIN'
YOUNYVERSE!



EEEP!



IT'S NOT A MATTER OF SHRINKING THE
UNIVERSE, OR SLOWING THE PASSAGE OF
TIME. DISTANCES AND TIMES ARE ONLY
APPEARANCES. EVERYTHING IS AN ILLUSION
AND NOTHING IS ABSOLUTE. THAT'S THE
WORLD OF RELATIVITY.



SO WHAT **IS** THE UNIVERSE LIKE?

IT DEPENDS ON THE SPEED OF THE OBSERVER.


SPEED RELATIVE TO WHAT?

THE ESSENTIAL IDEA IS THAT TWO PEOPLE
GOING AT THE SAME SPEED V IN THE SAME
DIRECTION SHOULD SEE - AND EXPERIENCE -
THE UNIVERSE IN THE SAME WAY.

BUT BACK TO COSMIC PARK. YOU'LL SEE THAT FOR SOME BEINGS,
THE UNIVERSE HAS A SINGULAR ALLURE...

WHEN TIME STANDS STILL


OR:
LIFE AMONG
THE
PHOTONS




DON'T THERE EXIST A SPEED WOT
MAKES THE SUBMARINE DIVE TO A DEPTH
WHERE THE HEXTERYOR PRESSURE EQUALS
THE PRESSURE IN THE RESERVOIR?

CRIPES! WOT
'APPENS
THEN?

LOGICALLY, TIME
SHOULD STOP...




WHATEVER
THAT
MEANS...



IN MR. ALBERT'S COSMIC PARK MODEL OF
THE UNIVERSE, THAT HAPPENS WHEN YOU REACH
THE CENTER OF THE SPHERE OF WATER.

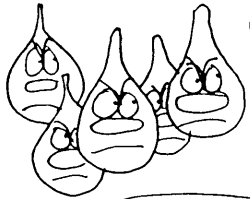
THAT'S THE DEPTH YOU REACH
WHEN YOUR SPEED IS 300,000 KM/SEC.

NOW WE'RE REALLY
GEETING TO THE **BOTTOM** OF
THINGS! THIS IS REALLY DEEP
THINKING.





DOES ANYTHING EXIST AT THE BOTTOM OF ALL THIS CHRONOS, AT THE CENTER OF THINGS, WHERE REIGNS THE ABSOLUTE ZERO OF TIME?



TIME - THAT'S FOR OTHER FOLKS TO WORRY ABOUT.

YES - PHOTONS.

THE CONSTITUENT PARTICLES OF LIGHT.

WE DON'T BOTHER WITH THAT STUFF!



EVEN SO, I CAN STILL MEASURE HOW FAST PHOTONS TRAVEL. THEY MOVE THROUGH A DISTANCE D IN A TIME t , AND THEIR SPEED IS $D/t = 300,000 \text{ KM/SEC}$. I HAVE A FUNNY FEELING I'VE SEEN THAT NUMBER BEFORE...

THEY'RE BORN - THEN THEY DIE - IN A FLASH!

BLEB
BLEB



YES - THAT REALLY IS LIFE IN THE FAST LANE...

EXISTING IN TIME, THAT'S JUST YOUR WAY OF LIFE. PHOTONS HAVE A DIFFERENT LIFESTYLE. FOR THEM BIRTH AND DEATH ARE TWO CONSECUTIVE EVENTS.

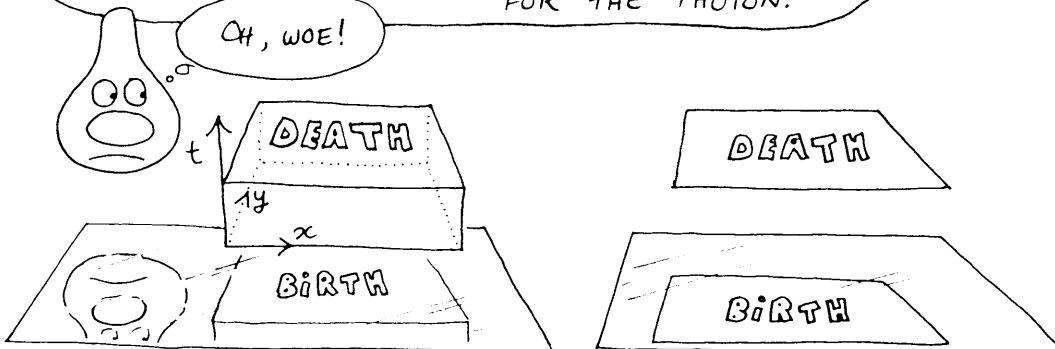


DOES THAT MEAN THAT FOR PHOTONS, THERE'S NO SENSE TO TIME?

THE PROPER TIME OF THE PHOTON TAKES PLACE IN AN INFINITELY THIN PRESENT, SANDWICHED BETWEEN THE INSTANT OF ITS BIRTH AND THE INSTANT OF ITS DEATH. CONSIDER A THREE-DIMENSIONAL SPACE-TIME WITH COORDINATES (x, y, t) . IF YOU FLATTEN IT IN THE TIME DIRECTION YOU'RE LEFT WITH A SURFACE THAT STILL HAS TWO SIDES. THE DISTINCTION BETWEEN THESE TWO SIDES DEFINES THE DIRECTION OF TIME FOR THE PHOTON.



Oh, woe!



YOU SEE, ARCHIE, EVERYTHING IS RELATIVE. TO LEARN TO THINK LIKE A PHOTON, YOU HAVE TO LIVE LIKE A PHOTON. WHICH IS DIFFICULT, BECAUSE PHOTONS DON'T LIVE!

I'M STILL HOPING SOMEONE'S GOING TO TELL ME WHY TIME RUNS FROM THE PAST TO THE FUTURE, INSTEAD OF THE OTHER WAY ROUND!

BLEB
BLEB

DOES IT MATTER?
AS TIME PASSES, WE ALWAYS MOVE WITH IT IN THE SAME DIRECTION.

I'M GETTING THE IMPRESSION THAT IF SOMEBODY SUDDENLY REVERSED THE DIRECTION OF TIME, NOBODY WOULD NOTICE!

'AVE YOU GORN BONKERS,
OR WOT?

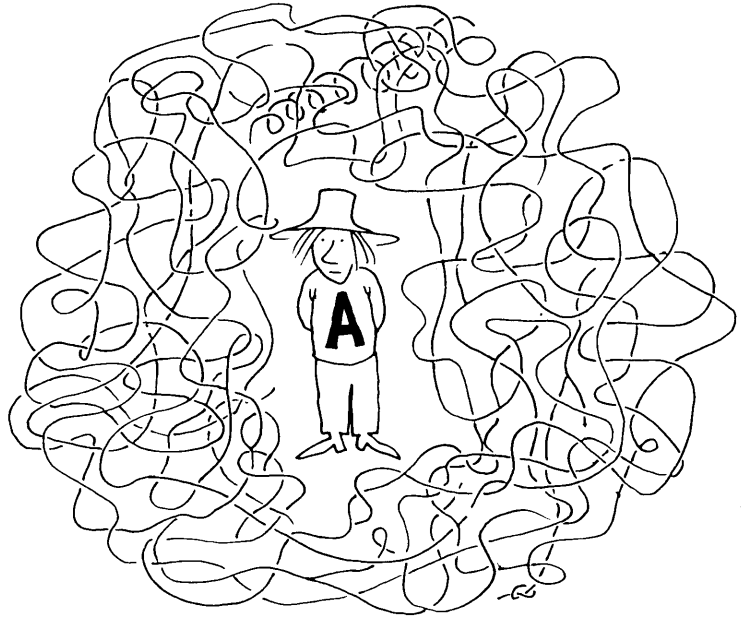
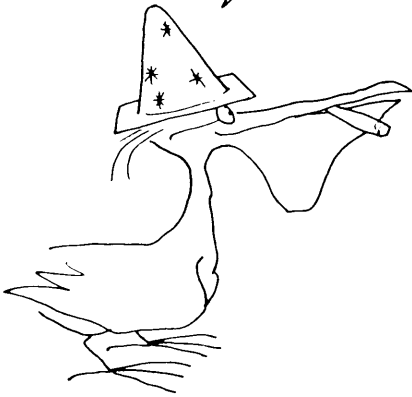


YOU KNOW, I THINK I'D QUITE ENJOY BEING A PHOTON - EVEN IF ONLY FOR AN INSTANT - TO GET AN IDEA OF HOW THEY VIEW THE UNIVERSE.



IT'S NOT POSSIBLE TO DRAW A 4-DIMENSIONAL SPACE-TIME. BUT YOU CAN, IN THREE DIMENSIONS, SKETCH THE INTERTWINED TRAJECTORIES FOLLOWED BY ALL OF THE OBJECTS IN THE UNIVERSE (THAT IS, ALL PARTICLES) AS THEY WOULD BE SEEN BY A HYPOTHETICAL OBSERVER WHO IS AT REST.

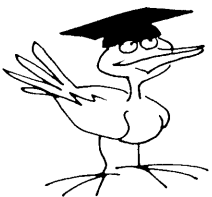
A SORT O' PIN-UP PHOTO IN THREE DIMENSIONS...



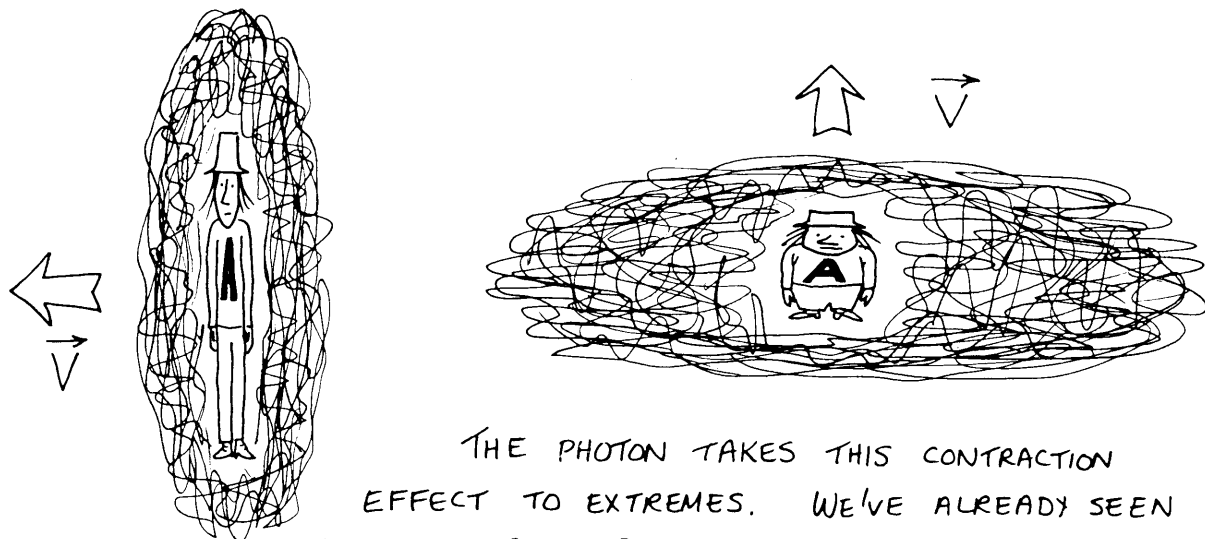
A REAL CAN OF WORMS!



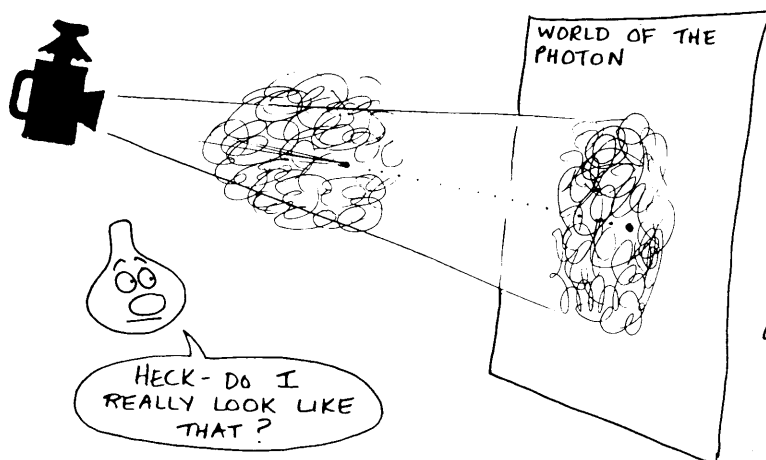
YOU GET SOMETHING LIKE A PLATE OF SPAGHETTI, OR THE LOS ANGELES FREEWAY SYSTEM...



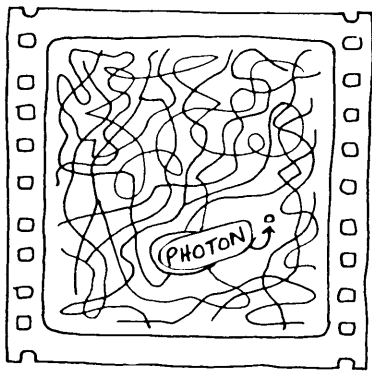
AS FAR AS LENGTHS GO, THIS UNIVERSE IS ELASTIC. IF ANOTHER OBSERVER MOVES AT A VELOCITY \vec{V} IN SOME DIRECTION, THEN EVERYTHING HAPPENS AS IF THE UNIVERSE (AND THE OBSERVER) HAS SHRUNK IN THIS DIRECTION.



THE PHOTON TAKES THIS CONTRACTION EFFECT TO EXTREMES. WE'VE ALREADY SEEN HOW ITS PROPER TIME IS SQUASHED COMPLETELY FLAT. IF IT COULD PERCEIVE THE UNIVERSE, IT WOULD APPEAR TO BE FLATTENED LIKE A PANCAKE ALONG THE DIRECTION OF MOTION. SO THE PHOTON INHABITS A TWO-DIMENSIONAL WORLD... AND THE PHOTON ITSELF IS SITUATED WITHIN THAT WORLD LIKE A SMALL, FLAT SCRIBBLE.

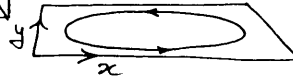
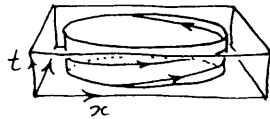
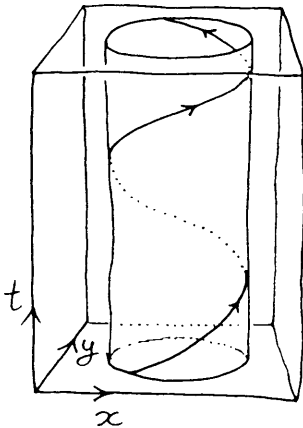


IT'S RATHER LIKE THE EFFECT YOU'D GET BY PROJECTING ON TO A SCREEN A PICTURE OF A BALL OF SPAGHETTI (AS SEEN BY A MOTIONLESS OBSERVER) USING A LAMP WHOSE AXIS IS ALIGNED WITH THE DIRECTION IN WHICH THE PHOTON IS MOVING.

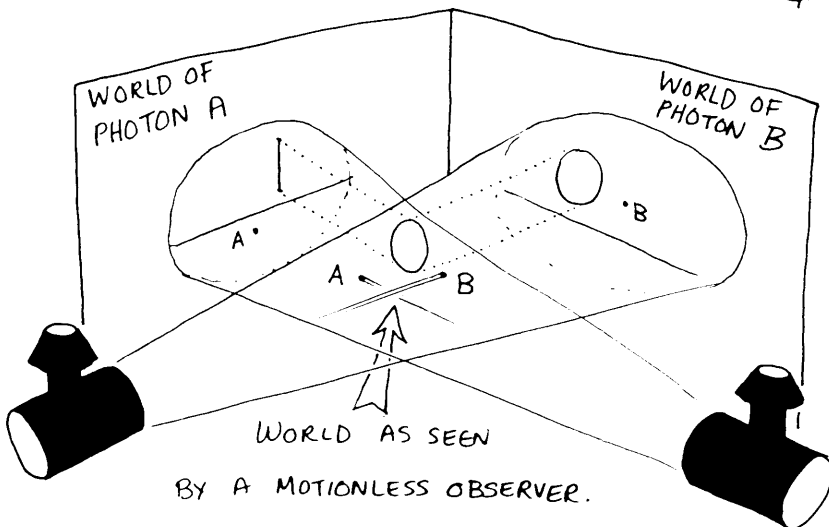


GRAND PREMIÈRE:
WORLD OF THE PHOTON

LIKE THIS...



SQUASHED LIKE THIS ALONG
ITS TIME-AXIS, THE SPIDER-TRACK
BECOMES A CIRCLE AGAIN!



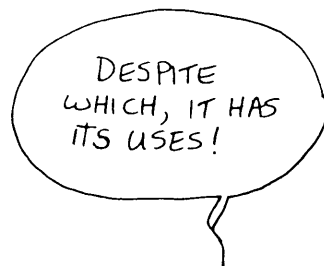
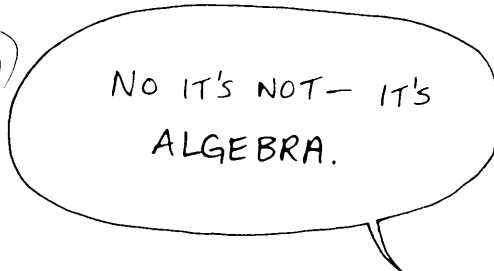
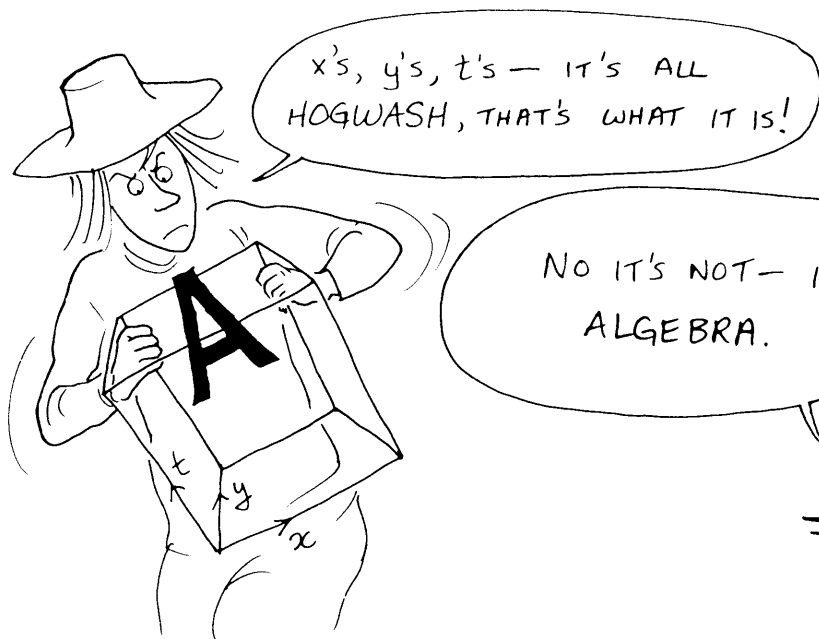
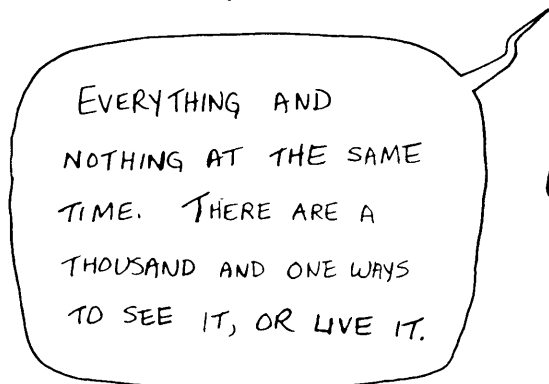
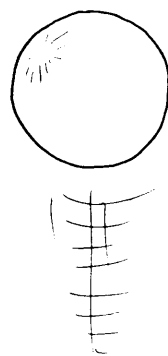
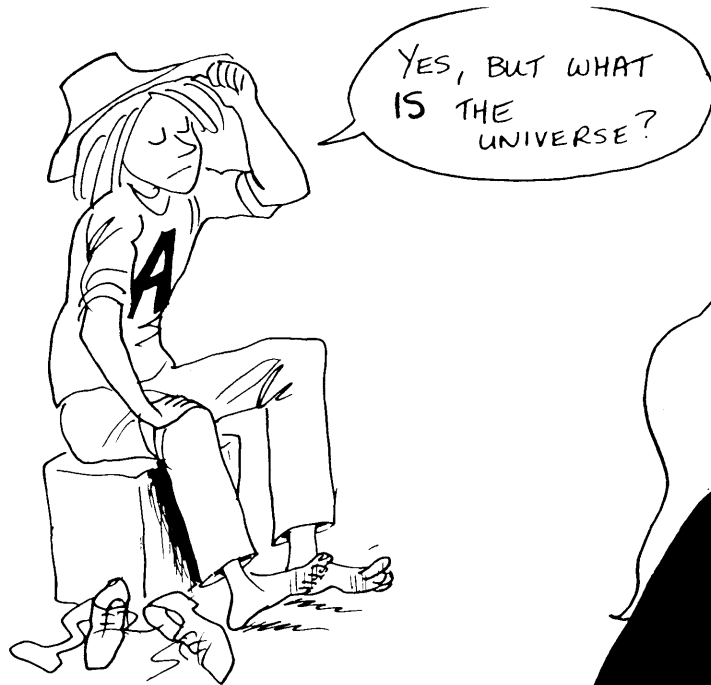
TWO PHOTONS TRAVELING
IN DIFFERENT DIRECTIONS
HAVE VERY DIFFERENT
VIEWS OF THE WORLD.

GOSH!



TO UNDERSTAND THE
PHOTON'S WORLD YOU
SHOULD IMAGINE TAKING
A FILM BY POINTING THE
CAMERA ALONG THE
DIRECTION OF MOTION
AND SUPERIMPOSING ALL
OF THE FRAMES.

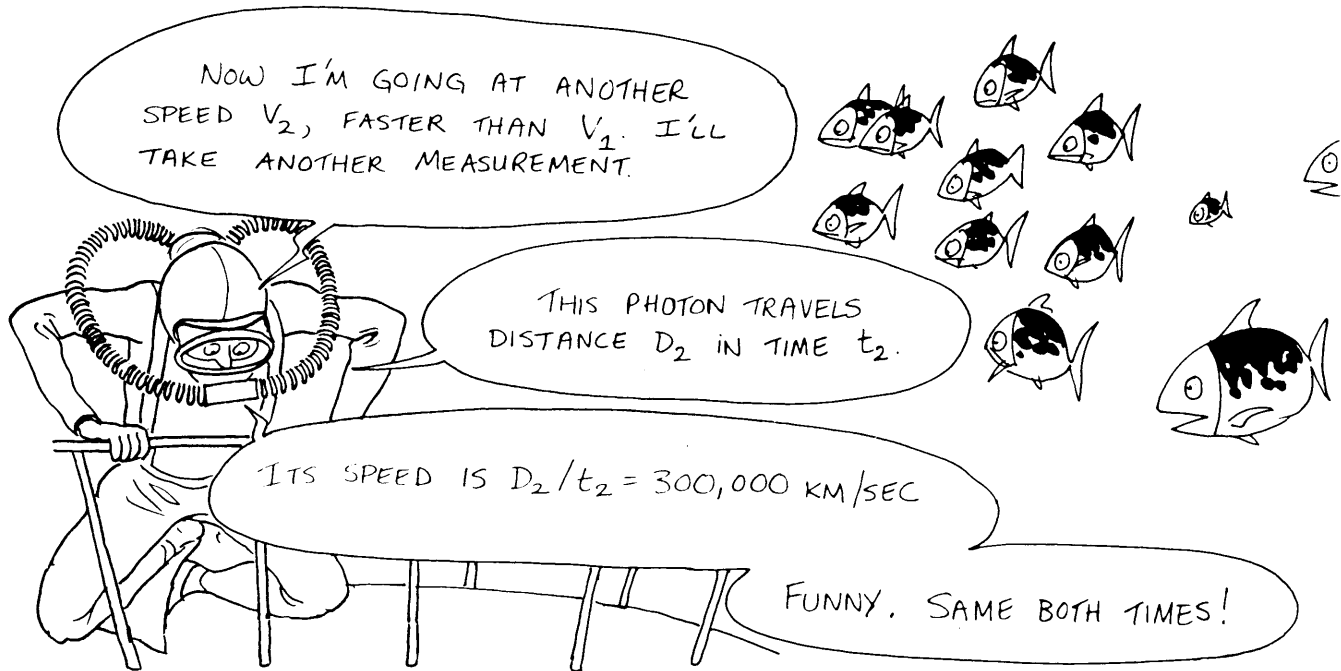




INVARIANCE OF THE SPEED OF LIGHT VARIATION OF MASS

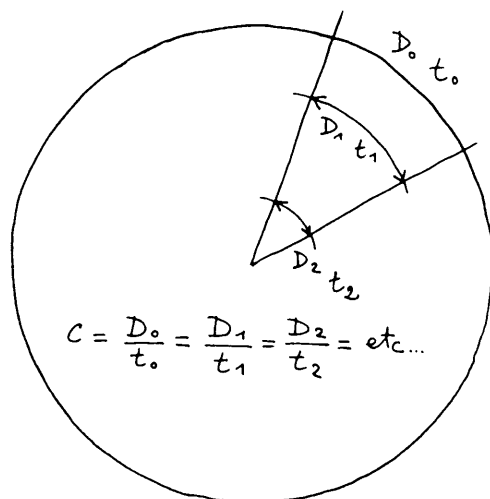




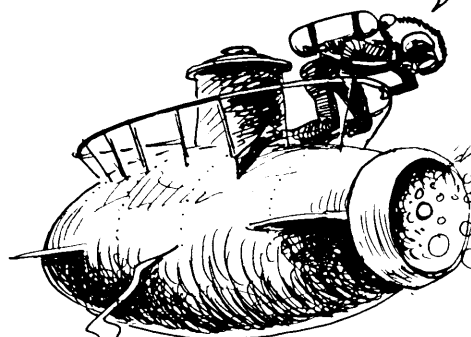


ALL OBSERVERS, WHATEVER THEIR VELOCITY, GET THE IDENTICAL VALUE c WHEN THEY MEASURE THE SPEED OF PHOTONS - THE FUNDAMENTAL PARTICLES OF LIGHT. THEY OCCUPY A SPECIAL PLACE IN COSMIC PARK. EVERYTHING HAPPENS AS IF THEY BEHAVED LIKE SMALL SEARCHLIGHTS WHOSE 'RAYS' MOVE AT A CONSTANT ANGULAR VELOCITY, PROJECTING THEIR IMAGES ON ALL OF THE CONCENTRIC SPHERES THAT GO TO MAKE UP **CHRONOS**. BECAUSE OF COMPENSATING CHANGES IN DISTANCES AND PROPER TIMES, OBSERVERS INVARIABLY FIND THAT $c = D/t = 300,000 \text{ KM/SEC}$.

THIS ABSOLUTE CONSTANCY OF THE SPEED OF LIGHT (THAT IS, THE SPEED OF PHOTONS) WAS FIRST OBSERVED EXPERIMENTALLY BY MICHELSON AND MORLEY IN 1881. THIRTY-FOUR YEARS LATER, IN 1915, EINSTEIN THREW THE TRADITIONAL MODEL OF SPACE-TIME OUT THE WINDOW, BECAUSE IT WAS INCOMPATIBLE WITH THIS INVARIANCE. HE SET ABOUT FINDING A NEW SPACE-TIME, THAT OF RELATIVITY. COSMIC PARK GIVES US SOME IDEA OF WHAT THIS IS LIKE.



WE'VE NEARLY GOT 'EM
NOW! FASTER, MR. ALBERT,
FASTER!



BLEB

BLEB

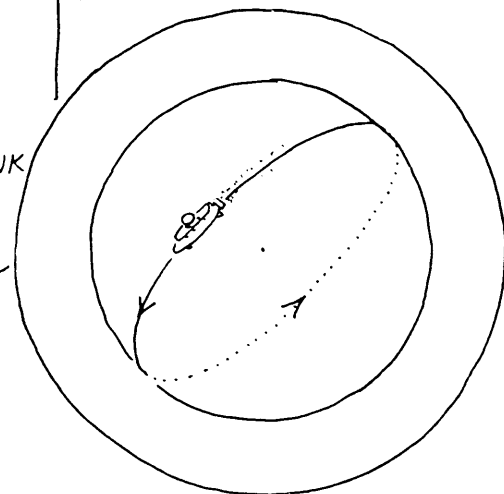
BLEB

IMPOSSIBLE,
MY BOY!

WHY?

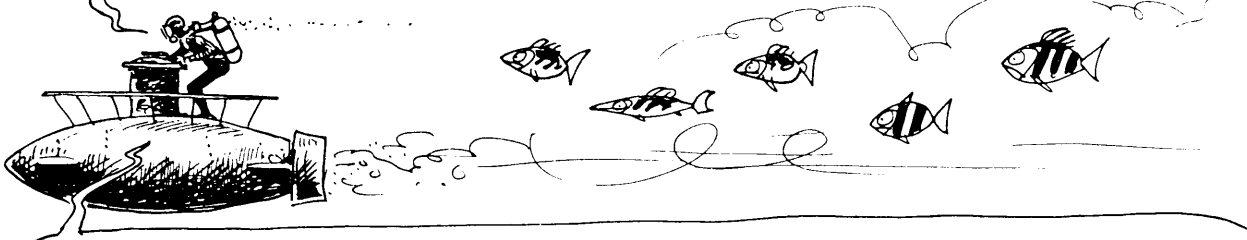


My SUBMARINE IS PROPELLED BY REACTION.
CHRONOS DOES NOT RESIST FORWARD MOTION:
ALL I HAF' TO DO IS TO OVERCOME DER
INERTIA. VEN I REACHES A SPEED V , UND
CUTS DER MOTOR, DER SUBMARINE FOLLOWS A
GREAT CIRCLE ON DER SPHERE CORRESPONDINK
TO DAT DEPTH (*).



(*) IN OTHER WORDS, A GEODESIC ON
THE SPHERE. SEE HERE'S LOOKING
AT EUCLID, SAME SERIES.

SO WHAT'S THE PROBLEM? START UP THE MOTOR AGAIN AND KEEP ACCELERATING. THEN WE'LL SOON CATCH UP WITH THOSE DRATTED PHOTONS!



I'M AFRAID NOT, ARCHIBALD. DER DEEPER VE GOES, DER DENSER GETS DER CHRONOS. DER MORE VE DESCENDS, DER MORE CHRONOS GETS INTO DER BALLAST TANKS, UND VE GETS TERRIBLE HEAVY. OUR MASS INCREASES.

MEMORANDUM:

WE WISH TO DISPEL A COMMON MISCONCEPTION - THAT EXERCISE MAKES YOU LOSE WEIGHT. ACTUALLY, THE OPPOSITE IS TRUE! THE SIMPLE ACT OF LEAVING A REST STATE (MASS m_0) INCREASES THE MASS m ACCORDING TO THE RELATION $m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$ OF COURSE, WHEN

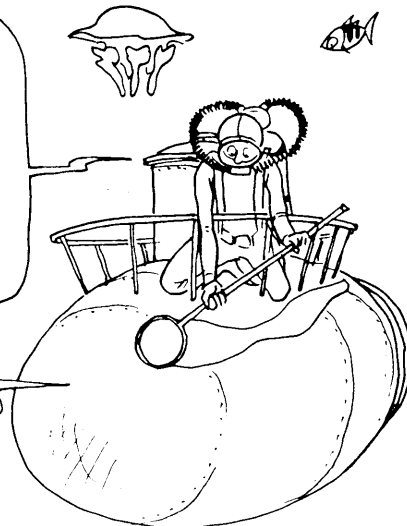
YOU STOP, YOU RETURN TO YOUR ORIGINAL MASS m_0 .

The Boss

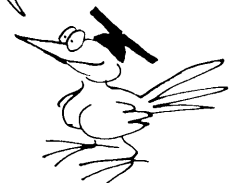


IT'S VERY FRUSTRATING!
WE'RE ALMOST THERE -
0.995 c, AND I CAN
ALMOST REACH OUT AND
TOUCH THEM - BUT NOT
QUITE!

AND OUR MASS HAS
INCREASED TENFOLD -
WE CAN'T GO ANY
FASTER!



FOR $V = 0.99999 c$
THE MASS WOULD BE 224
TIMES AS LARGE...
AND SO ON.



GOINK ON VOULD SURF NO USEFUL PORPOISE...
VE IS CONSUMINK AN INFINITE AMOUNT OF ENERGY
IF VE CHASES DER PHOTONS. GET READY,
I'M SURFACING!

OH,
SHUCKS!

WROAR! (()

PHEEEEW! YOU WON'T
GET THAT AT
DISNEYWORLD!

IF I UNDERSTAND YOU, THE MORE ENERGY YOU GIVE
TO A BODY, THE GREATER ITS MASS BECOMES.

JA. DAT MAKES SENSE, BECAUSE DER MASS
UND DER ENERGY ARE DER SAME T'ING.

$$E = m$$



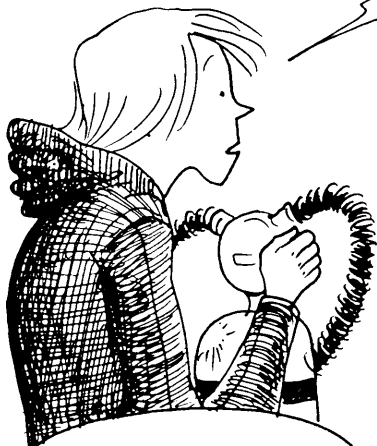
VELL — UP TO A CONSTANT
FACTOR... VICH IS DER SQUARE OF c .
SO VE CAN WRITE $E = mc^2$.
HMMM... IT'S A SIMPLE MATTER OF
UNITS. IF OUR UNIT OF LENGTH VAS
300,000 KM DEN VE'D HAVE YUST:

$$E = m$$

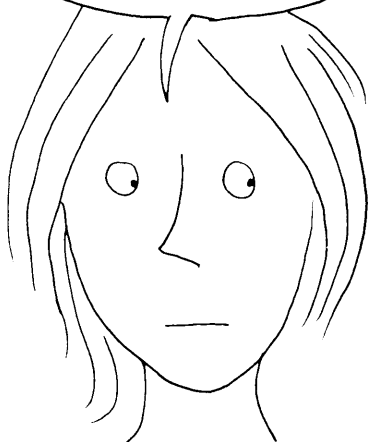
WHERE DOES THIS VALUE FOR c OF
300,000 KM/SEC COME FROM?



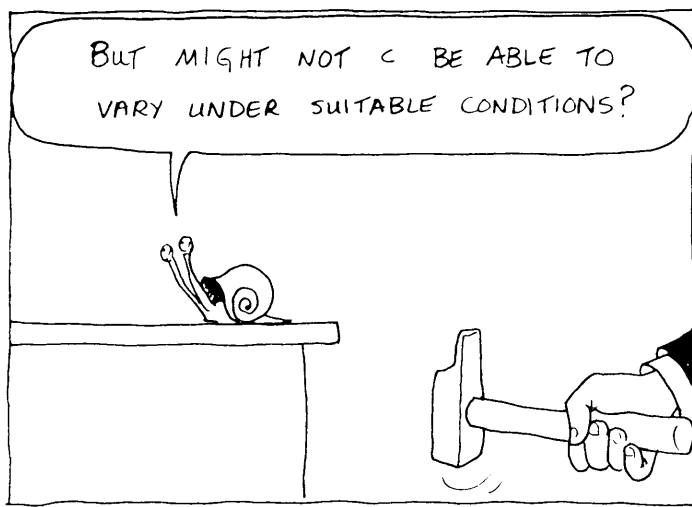
IF I VAS YOU, I'D PUT IT DER UDDER
WAY ROUN'. VERE DOES DESE KILOMETERS
AND SECONDS COME FROM?



I — ER — WHAT?



c IS THE UNIT OF SPEED PAR EXCELLENCE. THE
UNIVERSAL COSMIC STANDARD. THE KILOMETER
PER SECOND IS JUST A MISERABLE SUBMULTIPLE.



BUT MIGHT NOT ϵ BE ABLE TO
VARY UNDER SUITABLE CONDITIONS?



Ouch!

WATCH IT,
TIRESIAS!

ANOTHER
RUDDY
EPISTOCOP(*)

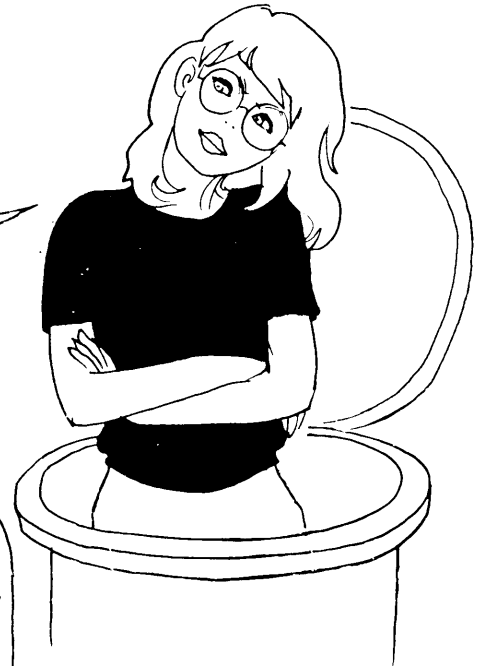
IT'S YOUR FINAL WARNING!

SOPHIE! YOU
FOLLOWED US!

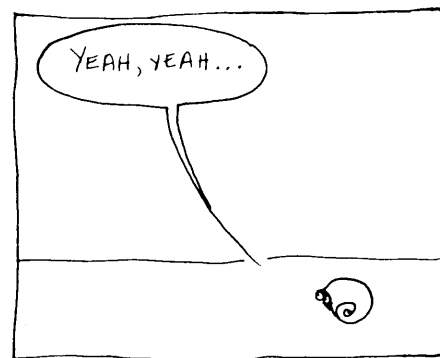
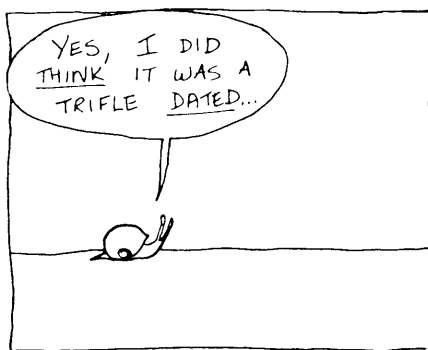
YES, THE REST OF
US CAME IN SUBMARINE #2.
YOU DIDN'T WANT TO COME
BACK AND FIND ME A
GREY-HAIRED OLD LADY,
DID YOU? ..

OH, CRUMBS, I FORGOT ABOUT
THE EFFECTS ON AGING!

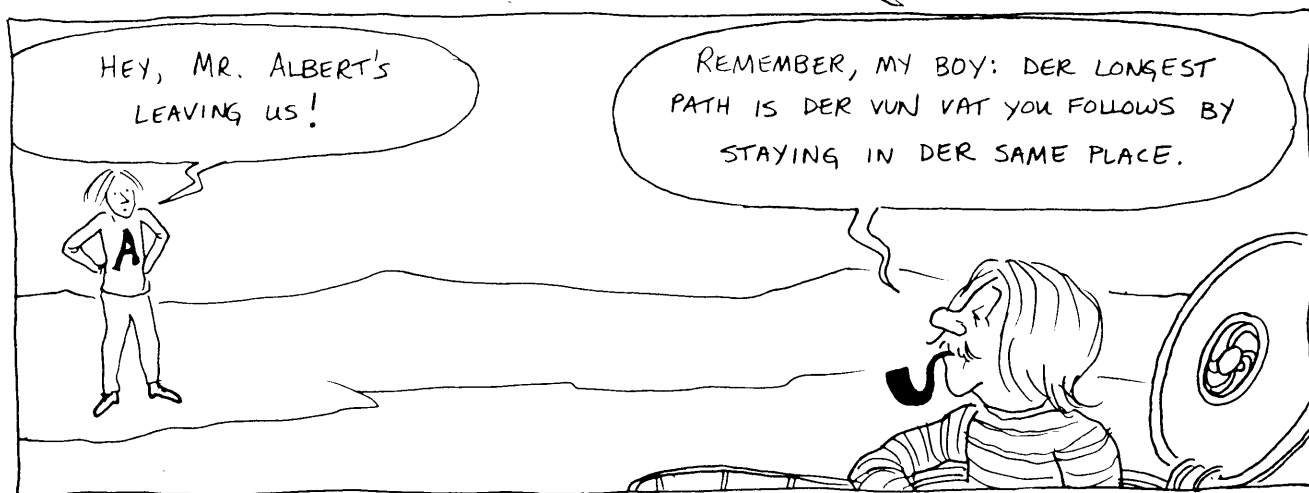
YOU MEN NEVER REMEMBER
ANYTHING. IT'S A GOOD THING
YOU'VE GOT US WOMEN TO DO
IT FOR YOU!



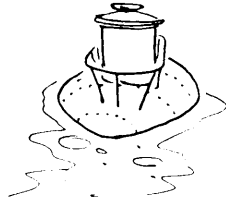
WOO-OOPS... LOOK HOW OLD COSMIC PARK'S GOT!



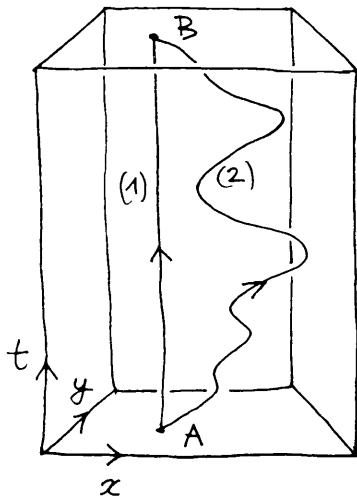
THE EDIFICE OF SCIENCE IS SUBJECT TO PARADIGM-SHOCK. OVER AND OVER AGAIN IT CRACKS, COLLAPSES, AND IS REBORN FROM ITS OWN RUINS.



Now, I wonder
WHAT HE MEANT BY
THAT?

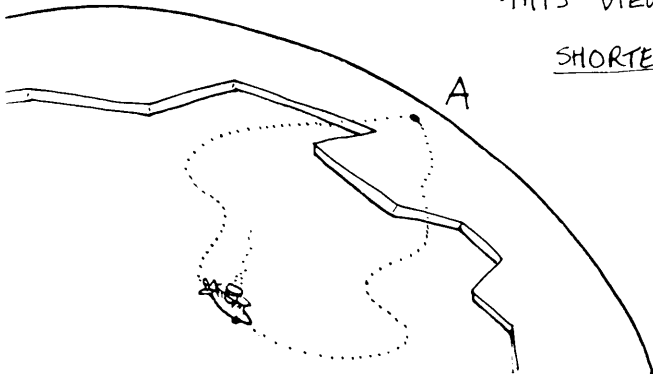


JUST THAT, IN SPACE-TIME,
THE STRAIGHT LINE (1) FROM A TO B
IS THE LONGEST PATH BETWEEN THEM.

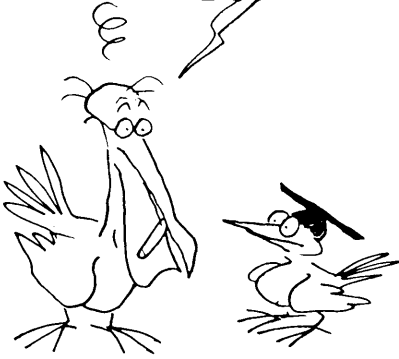


FOR INSTANCE, THE STRAIGHT SEGMENT \overline{AB}
IS THE PATH YOU'D FOLLOW IF YOU WERE
MOTIONLESS. THE CURVED PATH (2) BRINGS
EFFECTS OF VELOCITY INTO PLAY. WE'VE ALREADY
SEEN THAT WHEN YOU MOVE, YOUR PROPER TIME
(THAT OF THE TRAVELER, NOT OF A STATIONARY
OBSERVER) FLOWS MORE SLOWLY.

THE TRUE MEASURE OF DISTANCE, IN SPACE-TIME,
IS HOW MUCH PROPER TIME HAS PASSED. SO FROM
THIS VIEWPOINT, THE CURVED PATH BECOMES
SHORTER THAN THE STRAIGHT ONE.



IT'S STUPID, HAVING TO
FOLLOW A PATH TER STAY IN
THE SAME PLACE!



THE IMPOSSIBLE JOURNEY

NIGHT FALLS IN
COSMIC PARK

SOPHIE - WHAT
ARE STARS?

SUNS
LIKE OUR
OWN.

OUR STAR HAS ITS OWN
PLANET: THE EARTH. DO YOU
THINK THAT OTHER STARS
MIGHT ALSO HAVE THEIR
OWN PLANETS?

SURE, ARCHIE.



HOW FAR AWAY IS
THE NEAREST STAR?

LIGHT TAKES FOUR YEARS TO
REACH US FROM OUR NEAREST NEIGHBOR,
PROXIMA CENTAURI.

THAT'S...
40 TRILLION KILOMETERS!

WHEREAS PLUTO, OUT ON THE
EDGE OF THE SOLAR SYSTEM, IS
ABOUT 5 BILLION KILOMETERS - THAT
IS, 5 LIGHT-HOURS.

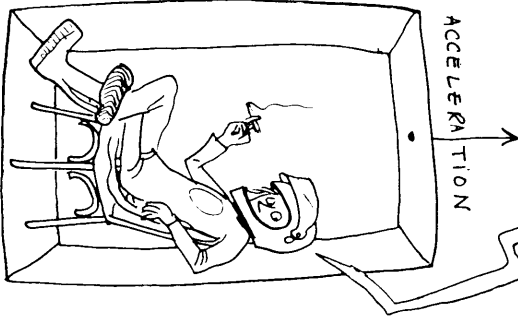
SO PROXIMA CENTAURI IS TEN THOUSAND TIMES
FURTHER AWAY... GOSH, THE UNIVERSE IS A BIG
PLACE!

MR. ALBERT EXPLAINED TO ME THAT YOU'D NEED RIDICULOUS AMOUNTS OF ENERGY TO APPROACH THE SPEED OF LIGHT. I WONDER... SUPPOSE I WANT TO GO AT 100,000 KM/SEC...

SUPPOSE I HAD A FUSION MOTOR THAT COULD ACCELERATE MY SPACECRAFT AT ONE "g" (THE ACCELERATION DUE TO GRAVITY AT THE EARTH'S SURFACE). THEN IN EACH SECOND MY SPEED WOULD INCREASE BY 10 M/SEC.



HERE IS HIGGINS'S TWO-ROOM APARTMENT: KITCHEN AND BATHROOM.

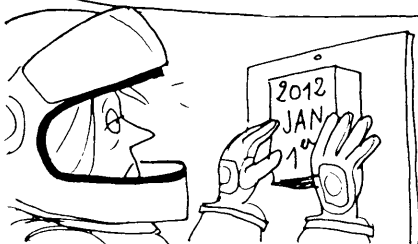


MY APPARENT WEIGHT IS JUST AS IT IS ON EARTH, SO I CAN SUPPORT IT FOR AS LONG AS I WISH.

AT THIS RATE IT WILL TAKE ME FOUR MONTHS TO REACH MY TOP SPEED OF 100,000 KM/SEC. DURING THAT TIME, I'LL ONLY COVER ONE HUNDREDTH OF THE DISTANCE.

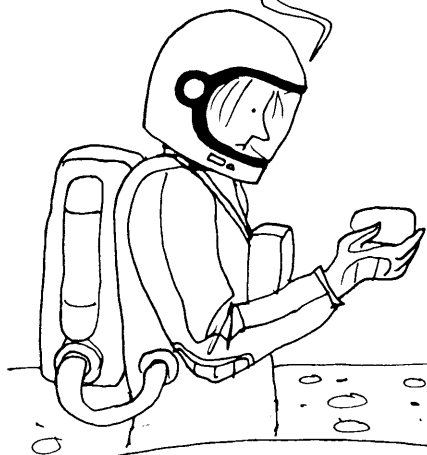


THEN THE REST OF THE TRIP WILL TAKE A MERE TWELVE YEARS... PLUS FOUR MONTHS TO SLOW DOWN AGAIN...

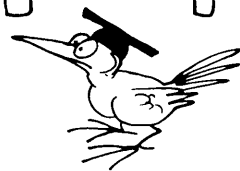
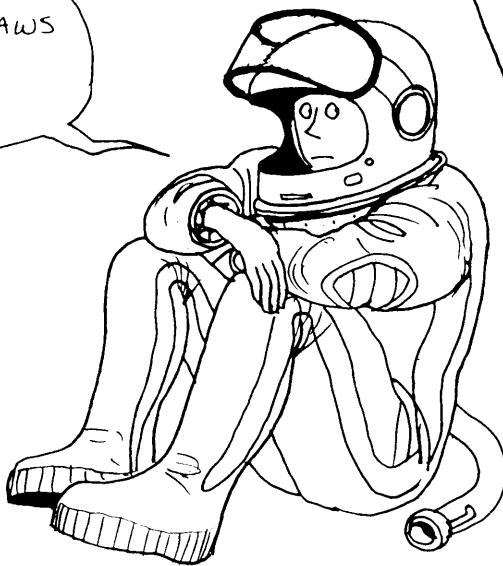
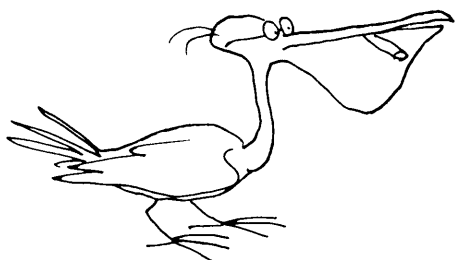


AND THE SAME AGAIN
IF I WANT TO COME BACK
TO TELL PEOPLE WHAT I
FOUND THERE...

YES... AND ALTHOUGH THERE'S
PRECIOUS LITTLE CHANCE THAT WE'RE
THE ONLY LIVING CREATURES IN THE
UNIVERSE, THE NEAREST INHABITED
PLANET (IF THERE IS ONE) WILL PROBABLY
BE A LOT FURTHER AWAY THAN
FOUR LIGHT-YEARS!



YOU'RE TELLING ME THAT
STAR-TRAVEL ACCORDING TO THE LAWS
OF COSMIC PARK IS A LIFETIME
CAREER.



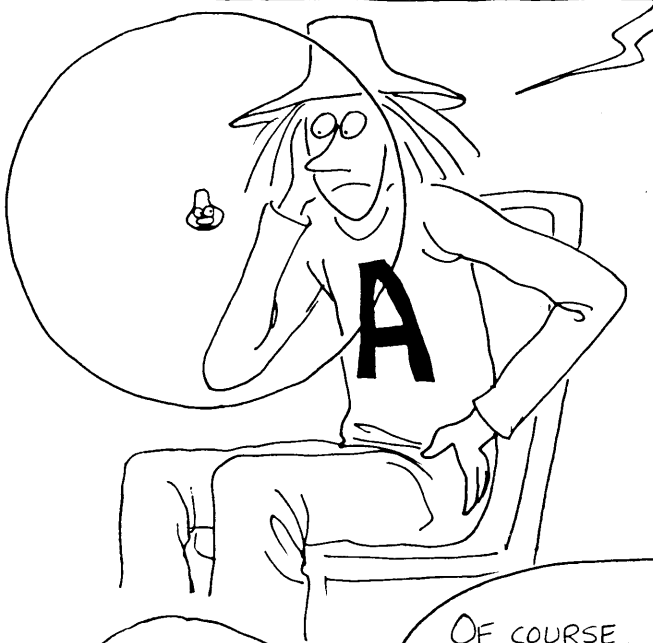
SO...
WHAT TO DO?

IS THE VOYAGE
FOREVER IMPOSSIBLE?

DOES THE LAD
NEVER GIVE UP?



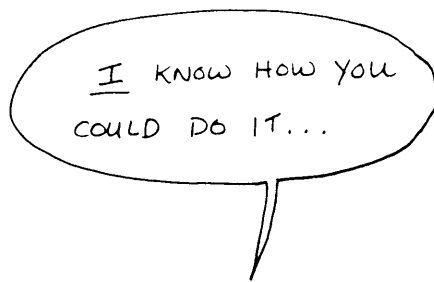
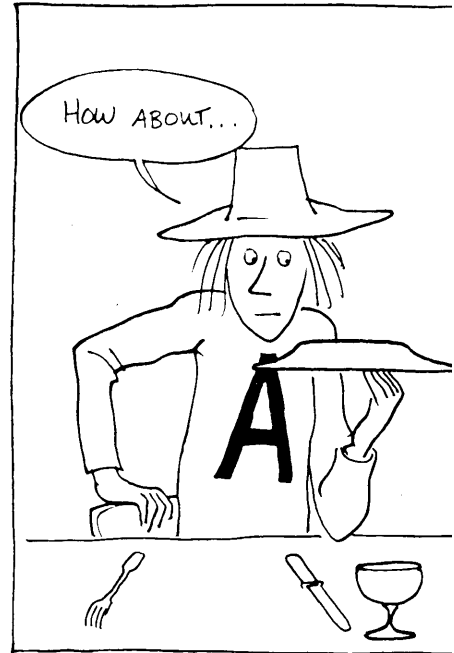
TO GO FASTER THAN THE SPEED OF LIGHT MAKES NO SENSE.
IT'S LIKE TRYING TO DIVE DEEPER THAN THE CENTER
OF COSMIC PARK!



OF COURSE, COSMIC PARK
MAY NOT BE THE
ULTIMATE MODEL.



VERY LIKELY. BUT THAT DOESN'T
TELL ME HOW TO REACH THE STARS
IN A REASONABLE TIME.



THE END